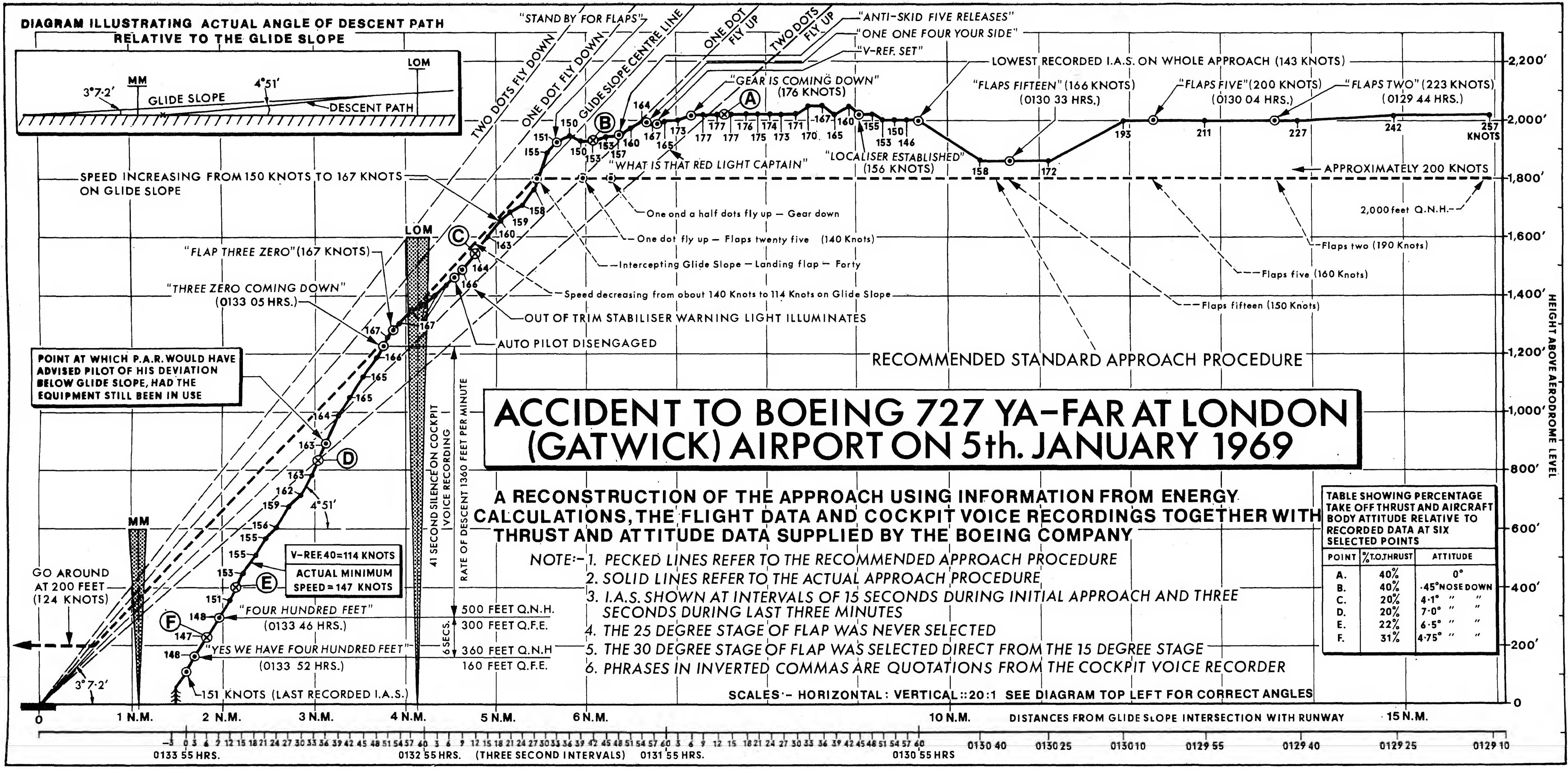
Fig. 1



ACCIDENT TO BOEING 727 YA-FAR AT LONDON (GATWICK) AIRPORT ON 5th. JANUARY 1969

A RECONSTRUCTION OF THE APPROACH USING INFORMATION FROM ENERGY CALCULATIONS, THE FLIGHT DATA AND COCKPIT VOICE RECORDINGS TOGETHER WITH THRUST AND ATTITUDE DATA SUPPLIED BY THE BOEING COMPANY

NOTE:–
1. PECKED LINES REFER TO THE RECOMMENDED APPROACH PROCEDURE
2. SOLID LINES REFER TO THE ACTUAL APPROACH PROCEDURE
3. I.A.S. SHOWN AT INTERVALS OF 15 SECONDS DURING INITIAL APPROACH AND THREE SECONDS DURING LAST THREE MINUTES
4. THE 25 DEGREE STAGE OF FLAP WAS NEVER SELECTED
5. THE 30 DEGREE STAGE OF FLAP WAS SELECTED DIRECT FROM THE 15 DEGREE STAGE
6. PHRASES IN INVERTED COMMAS ARE QUOTATIONS FROM THE COCKPIT VOICE RECORDER

SCALES:– HORIZONTAL : VERTICAL :: 20:1 SEE DIAGRAM TOP LEFT FOR CORRECT ANGLES

TABLE SHOWING PERCENTAGE TAKE OFF THRUST AND AIRCRAFT BODY ATTITUDE RELATIVE TO RECORDED DATA AT SIX SELECTED POINTS

POINT	% T.O. THRUST	ATTITUDE
A.	40%	0°
B.	40%	·45° NOSE DOWN
C.	20%	4·1° " "
D.	20%	7·0° " "
E.	22%	6·5° " "
F.	31%	4·75° " "

B.O.T. (C.A.Dept.) C.Ops.10. D.O. Drg. No. 6010 8–1–70

CAP 348

DEPARTMENT OF TRADE AND INDUSTRY

Precision Approach Radar

Report of the inquiry into the need to retain PAR to monitor ILS approaches

LONDON: HER MAJESTY'S STATIONERY OFFICE

From 20 OCTOBER 1970 the Department of Trade and Industry assumed the functions of the Board of Trade

SBN 11 510433 X

Members of the inquiry

Chairman

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Preface

1 On 20 January 1969, Mr W T Rodgers, Minister of State, Board of Trade, announced in the House of Commons that there was to be a review of the decision that PAR should be withdrawn from airports in the United Kingdom.

2 We were invited to conduct an inquiry, with the following terms of reference:

"To examine and recommend whether there is a need to provide precision approach radar (PAR) to monitor, as a means of reducing the risk of accidents, the flight paths of aircraft making instrument landing system (ILS) approaches."

3 This report describes our inquiry. To assist the reader who may be unfamiliar with the background, it begins with a brief account of the arrangements for air traffic control and navigation in the vicinity of United Kingdom civil aerodromes, and the way in which ILS and PAR fit into these arrangements. We then include short accounts of the functional characteristics of ILS and PAR, and of the use of PAR to monitor approaches made with ILS as the primary aid. The number of landings requiring the approach aids depends on aircraft movements and meteorological conditions, and we include data for a few United Kingdom airports.

4 Against this introductory background, we describe the evidence that we have considered. We summarize first the opinions of organizations or individuals having special interests in our subject. We then consider the information that we have been able to collect about operational experience of approaches using ILS both with and without PAR monitoring. The main sources of this information are reports on accidents, the logs kept by air traffic controllers engaged in routine PAR monitoring, and the results of special studies in which the flight paths of aircraft making ILS approaches were independently recorded.

5 Our inquiry would not be complete without reference to the costs and manpower requirements of PAR monitoring, and these are considered together with data on the possible costs of accidents or delays that might be prevented by PAR monitoring. It also seemed necessary to explore whether there are factors (eg the introduction of automatic landing systems or aircraft types differing greatly from those in service) which are likely to affect the subject of our inquiry in the immediate future. Although not strictly within our terms of reference, we also felt it worthwhile to consider very briefly whether systems for monitoring ILS approaches might be devised which are less costly in funds and manpower than PAR.

6 The final sections of the report discuss the evidence mentioned above, and describe our conclusions and recommendations. Further details of topics summarized in the report are given as appendices.

7 We wish to record our thanks to all who have helped us in our work.

28 JA 1971

CHAPTER 1

Approach aids in current use

Air traffic control and navigation during the approach to landing

8 The objectives of the Air Traffic Services are to provide and maintain a safe, orderly and expeditious flow of air traffic. To achieve these objectives, the air traffic services in the United Kingdom are sub-divided into areas, within which all aircraft are subject to the direction of the Air Traffic Control Services, as follows:

(i) Area control — for air traffic en route in the airways;

(ii) Approach control — (a) for aircraft leaving the airways until they have landed or have been transferred to aerodrome control; (b) for departing aircraft from take-off until they have been transferred to area control;

(iii) Aerodrome control — for aircraft taxying, landing, taking off and flying within the aerodrome control zone.

9 This report is concerned only with the approach to landing phase of flight, ie (ii)(a) and (iii) above, and the role which Precision Approach Radar (PAR) and the Instrument Landing System (ILS) play in the conduct of that phase at United Kingdom airports.

10 The current procedure for an ILS approach to landing is that aircraft leaving the airways are guided by approach control, using surveillance radar, to a position where they may pick up the glide path of the ILS. Once established on the system, the aircraft is transferred to aerodrome control who check the final approach until the pilot has the runway in view.

11 ILS is the standard civil international approach aid and has now entirely replaced PAR as the primary approach aid at United Kingdom civil airports. Use of PAR as a secondary approach aid[1] has declined to a point where it remains in operation at Heathrow and Manchester only, and where it is employed solely as a monitor of ILS approaches in conditions of poor visibility.

Precision Approach Radar (PAR)

12 Precision Approach Radar is a radar system which enables the air traffic controller on the ground to give directions by direct voice radio communication to a pilot to enable him to maintain his aircraft on the required final approach path. The controller has two displays, one showing the aircraft's position in azimuth and the other showing the aircraft's position in elevation in relation to the glide path.

13 The first practical equipment was produced during the Second World War to meet a requirement for a Ground-Controlled Approach (GCA) system which would allow an aircraft approaching to land under conditions of poor visibility to be located and given oral instructions so that it could be brought near enough to the runway to complete a successful visual landing.

14 Basically, this equipment consisted of:

(a) A self-contained surveillance (10 cm) radar with a Plan Position Indicator (PPI) which was employed to locate and guide aircraft towards the airfield to a position where they could be controlled by a precision radar on the final approach path;

(b) A precision (3 cm) radar capable of showing the position in azimuth and elevation of all aircraft on the approach path;

(c) Radio equipment for two-way communication with the aircraft and the airfield control tower.

15 All these elements were contained in a mobile trailer and required two or three air traffic controllers to man the operating positions in the vehicle, plus other technical and auxiliary personnel.

16 The system was very successful in operation but there were limitations — operation was difficult in the crowded trailer which was also located away from the normal control tower, and the equipment was becoming obsolete — and it was redesigned so that the display equipment could be sited in the approach control room and operated by one man. The new system, which is still in use, consisted of:

---

[1] PAR is also used in connection with parallel runway operations and noise monitoring but these functions are outside the terms of reference of this Inquiry.

(a) A separate surveillance radar with its aerials located near to the runway in use;

(b) Two displays, one long range (10 nm) and one short range (3 nm) each indicating the aircraft's position in azimuth and elevation in relation to the glide path, located in the control tower.

17 The operational standards required for a Precision Approach Radar for civil use have been agreed by the International Civil Aviation Organization (ICAO) and are incorporated in Annex 10 to the Convention on International Civil Aviation. Relevant details from this annex are reproduced as Appendix 1 to this report.

18 ICAO now recommends the provision of PAR only in the following circumstances:

(a) If Air Traffic Control will be materially assisted in the handling of traffic intending to use ILS. In the United Kingdom the airport approach radar is used instead;

(b) To provide a service for aircraft without the necessary airborne ILS equipment. Nowadays all commercial aircraft carry ILS;

(c) At airfields where the provision of ILS is not technically possible.

19 The Royal Air Force, however, places greater reliance on PAR because of the difference in their mode of operations. The RAF must provide, for example, for the handling of battle-damaged aircraft or pilots suffering from combat stress or for "one-pilot" aircraft, and their airfields with ILS may also be used by aircraft not equipped to use it. PAR is, therefore, normally provided in addition to ILS.

Instrument Landing System (ILS)

20 The Instrument Landing System is a pilot-interpreted approach aid which provides directional and glide path information in a visual form to enable a pilot to maintain the correct glide path. The information is displayed on an instrument in the cockpit in one of two ways; it can indicate the position of the aircraft in relation to the correct approach path or it can indicate the appropriate manoeuvre to correct any deviation from the approach path.

21 Previously, the function now served by ILS was performed by a system known as Standard Beam Approach (SBA) operating on HF which provided information in an aural form to the pilot, indicating by distinctive signal tones whether he was lined up with the runway centreline or to the left or right of it. Distance to touchdown was indicated to the pilot by additional signals from marker beacons. From this has developed the current ILS, operating on VHF and providing a highly accurate and continuous visual indication of the aircraft's position relative to an ideal glide path. Again, marker beacons provide distance to touchdown checks by both aural and visual indications in the cockpit.

22 ILS was first adopted as the standard civil international approach aid in 1946, since when it has been progressively installed at all airports used by international airlines. In addition to its function as an approach aid, ILS considerably assists in maintaining a regular flow of traffic and in achieving high runway utilization rates at busy airfields. For these reasons the carriage and use of ILS by aircraft landing at some of the busier airports, eg Heathrow, has been made mandatory.

23 The operational standards required for ILS for civil use have been agreed by the International Civil Aviation Organization (ICAO) and are incorporated in Annex 10 to the Convention on International Civil Aviation. Relevant details from this annex are reproduced as Appendix 2 to this report.

PAR monitoring of ILS approaches

24 The purpose of PAR monitoring is to provide a warning to the pilot if he should stray outside the safe approach funnel and to give advice if a dangerous situation appears imminent or if it appears that a missed approach may occur if appropriate action is not taken.

25 Air Traffic Control Instructions require ILS approaches to be monitored whenever the cloud ceiling is 300 feet or less and/or the Runway Visual Range (RVR) is less than 1100 metres. The pilot may, at any time, request PAR monitoring.

26 The limitations of PAR for monitoring ILS approaches are as follows:

(a) PAR is not so accurate as ILS. The glide paths of the two equipments may not exactly coincide and some allowance must be made for this to avoid conflict between small corrections by the controller and the indications of the cockpit instruments. At the same time, the controller must avoid "nagging" the pilot with small corrections which the pilot might be about to effect. The controller's instructions are, therefore, not to give corrections until an aircraft departs from a defined approach funnel. Consequently, there is a time lag while the controller observes a departure from the flight path. There may also be small inaccuracies due to reading error;

(b) In addition to the time lag at (a) a further interval is involved in transmitting a correction to the pilot, and in the pilot's reaction to it. Further delay occurs while the aircraft is responding to the controls.

27 The delay (a) on the part of the controller is of the order of 10 to 12 seconds to which must be added the pilot and aircraft delay (b), estimated at 8 to 10 seconds, to give a total delay of between 18 and 22 seconds. Depending upon the aircraft's rate of descent, the distance from the runway threshold at which it becomes critical as to whether the controller could effectively intervene could be as much as 3 miles, although there is evidence from the PAR logs and accident reports that helpful advice is often given much closer to the threshold.

28 A detailed explanation of the procedures and techniques employed when approaches are being monitored is given in Appendix 3. This information demonstrates how the critical distance from the threshold can be affected by various combinations of descent rate and forward speed.

Frequency of requirement of approach aids

29 The number of landings in which approach aids are required depends on the number of aircraft movements and on meteorological conditions. Data have been obtained for Heathrow, Manchester and Gatwick, and are summarized in Appendix 4.

30 The data show that during 1969 the numbers of landings requiring ILS were as follows:

Airport	*Number of landings requiring ILS*	*Percentage of total landings*
Heathrow	11,449	8·87
Manchester	1,452	5·59
Gatwick	4,037	9·25

31 There are, of course, considerable variations from month to month, the need for ILS being greatest in December and January. The maximum monthly percentages of landings requiring ILS to total landings are 19 per cent, 15·41 per cent and 22·95 per cent for Heathrow, Manchester and Gatwick respectively.

CHAPTER 2

Opinions of interested organizations and individuals

32 Many organizations and individuals have a keen interest in PAR monitoring, and we were aware that some of these had made special studies before our inquiry began. It was, therefore, important for us to secure their opinions and we have done this by correspondence or discussion. This chapter of our report summarizes the views expressed to us.

Airline operators

33 Sixty-four operators of scheduled services using United Kingdom airports were approached, and replies were received from thirty-eight including most of the major airlines. Extracts from these replies are reproduced in Appendix 5.

34 Three of the replies express clear opinions against the retention of PAR, arguing that the reliability of ILS and properly designed crew procedures make it redundant. Two replies suggest that in some circumstances PAR may worsen the position by distracting the crew from its primary monitoring tasks. On the other hand, seventeen operators feel that PAR monitoring contributes to safety. The remainder express no firm policy although several comment on the desirability of PAR monitoring in special circumstances, for example, where there are unusual local topographical or meteorological conditions.

35 Reference is made in several of the replies to the contribution of PAR monitoring to reducing the strain on the pilot, and to the fact that ILS approaches are often made at the end of a duty when the pilot may be tired. Three operators mention the potential contribution of PAR monitoring in detecting gross errors in ILS or its interpretation by the crew, and mention is also made of the detection of the consequences of altimeter mis-setting. Two operators refer to the special contribution that PAR may make in cases of damaged aircraft. Most of the replies are based on general considerations or experience but five operators mention specific examples where PAR monitoring was helpful in cases of, for example, ILS malfunction.

36 Several of the companies favouring the retention of PAR for the immediate future express the opinion that it will become less important with further development and refinement of ILS. With the advent of parallel runway approaches, several companies foresee a requirement for monitoring in azimuth because of the relatively small lateral separation of aircraft, but this topic is excluded from our terms of reference. One operator suggests that it would not be justified to retain PAR solely for the purpose of monitoring ILS landings on single runways, but where it is provided for other purposes, it should be used also for this purpose.

International Air Transport Association (IATA)

37 Because IATA represents all scheduled airlines, it can present a consolidated opinion and we therefore held a discussion with two representatives of the Association, Mr W Inglefield and Mr H Kershaw. They began the discussion by tracing the history of the relevant approach aids, referring to Ground-Controlled Approach (GCA) in the immediate post-war period, the subsequent development of PAR, and the introduction of ILS. At one time, the performance of PAR was comparable to that of ILS, but with the latest specification from the International Civil Aviation Organization (ICAO) it was doubtful whether PAR intervention in Category II or worse conditions would be effective. Board of Trade trials had proved that within ½ mile from touchdown PAR was ineffectual. It was, therefore, felt by IATA that the efficiency of modern ILS equipment rendered PAR of little value and that, rather than extend the use of PAR, it would be better to further improve and extend the ILS. All modern aircraft (ie those not more than 2–3 years old) were fitted with equipment capable of functioning to the current prescribed minimum conditions; in the United Kingdom legislation prevented older aircraft with less sophisticated equipment from attempting to operate to the same minima.

38 To a suggestion that PAR could detect excessive descent arising from altimeter errors, Mr Inglefield replied that all major operators now have procedures to guard against this eventuality. Any errors made by pilots of scheduled services involved violation of company policy. It was unlikely that crew fatigue could contribute to faulty approaches; legislation governed the hours to be worked.

39 It was the opinion of IATA that if PAR was

already in existence it should continue in use only where there was doubt about the accuracy or reliability of the ILS installation; PAR should not be extended to other airports. As regards parallel runway operations, PAR should be employed during the introductory phase. A demonstration of a PPI system for parallel runways had indicated that PAR would not be necessary; but some modifications were still required and PAR for azimuth observations would be needed for some time, especially at Heathrow. The DFTI (Distance From Touchdown Indicator) already in use in several countries including the United Kingdom gives satisfactory range separation.

40 Reference was made to the data (see Chapter 3) on the performance of aircraft on ILS approaches being collected by the Directorate of Operational Research and Analysis (DORA), Board of Trade, and that from the data so far gathered and analyzed it would appear that a few approaches (perhaps 1 per cent) were so far outside the normal deviations as to require further study, although there was no evidence that they led to potentially dangerous situations. The IATA representatives felt that it was unlikely that such deviations resulted from faults in ground or airborne equipment, and were more probably associated with the pilot.

41 IATA is pressing for the installation of ILS at all principal airports, even for good weather approaches, and felt that if the United Kingdom decided to retain the existing PAR installations or to extend the service to other airports purely to monitor ILS approaches there might be international repercussions which could delay the implementation of the ILS programme. It was the opinion of IATA that there is no requirement for PAR for monitoring if properly operating ILS (to Annex 10 standards) is available. There is, however, a case for PAR to monitor in azimuth parallel approaches until more operating experience has been gained.

Business Aircraft Users Association Ltd

42 In addition to aircraft on scheduled services, it is necessary to consider other aircraft which may make ILS approaches at United Kingdom airports. Business aircraft may be especially important in this context partly because their numbers seem likely to increase rapidly, and partly because their crew members or airborne ILS installations may differ from those of aircraft on scheduled services.

43 We accordingly approached the Business Aircraft Users Association for its views, and the Chief Executive replied as follows:

"A recent meeting of our members' pilots discussed at length the question of withdrawal of PAR and unanimously regretted the original decision, considering this a retrograde step from the safety point of view. They have always felt that the monitoring of the ILS has been a significant additional safety factor in their operations. It is appreciated that this factor may have a psychological element in its beneficial effect, but this effect is considered to be of significant importance in business aircraft operation."

United Kingdom Airport Authorities

44 Twenty-eight of the principal airport authorities, excluding the Board of Trade, were approached and the replies received from twenty-five are reproduced in Appendix 6. Nearly all the authorities feel that PAR monitoring contributes to safety, although several feel that the potential contribution is slight or exists only in special circumstances. Five authorities are not in favour of retaining PAR referring particularly to the capital and recurrent costs, but twelve others favour its use as a contribution to safety and efficiency of operation.

45 Many detailed arguments are advanced in favour of PAR monitoring. Attention is drawn to the relief of strain amongst pilots and protection against pilot error during an ILS approach. Mention is made of the value of PAR when ILS ground equipment is unserviceable during maintenance or airport modifications. Reference is made to its potential value in monitoring and controlling the horizontal separation of aircraft making ILS approaches especially when several aircraft with different speed potentials are concerned, and it is also suggested that PAR can contribute by detecting local-flying aircraft near the approach. It is argued that PAR monitoring should reduce the number of overshoots which adversely affect the movement rate at an airport, and a useful side benefit of PAR is thought to be the provision of height data for noise monitoring. In addition to the value of PAR when airborne ILS equipment is faulty, some authorities refer to its importance where aircraft not equipped with ILS form part of the traffic.

46 The detailed arguments advanced against the retention of PAR monitoring include its costs, although one authority feels that these become increasingly justifiable as the size and value of aircraft rise. It is also argued that the delay between the PAR operator detecting a significant deviation and passing the information to the pilot is too long for PAR monitoring to be effective during the final stages of an approach, especially for modern turbo-jet aircraft with high approach and sink speeds. Against this argument, one authority suggests that aural instructions provided by PAR are likely to be acted upon by the pilot more promptly in an emergency than the pilot's own interpretation of his ILS. The point is also made that,

although the crucial stage of landing is at or shortly before decision height, there is evidence that aircraft that break off approaches have often not been firmly established on the ILS glide path earlier. PAR warning of deviations during the early stages of an approach is, therefore, important as a contribution to regularity of service if not to safety. One authority suggests that if the main purpose of PAR monitoring is to warn the pilot of errors in his interpretation of ILS, it might be possible to achieve this objective more simply by other means. Several authorities refer to weather minima, some suggesting that they should be enforced more rigidly, and others that they should be adjusted according to the approach aid available or the operator's experience of using the airport.

International Civil Aviation Organization (ICAO)

47 Shortly before our inquiry began, the Board of Trade had sought the views of ICAO on the withdrawal of PAR facilities and the correspondence was made available to us. ICAO supplied excerpts from replies to an enquiry addressed to various foreign countries and these are reproduced in Appendix 7.

48 It will be seen that opinion is almost equally divided in foreign countries between those that see advantages in retaining or, in a few cases, extending PAR facilities, and those that have withdrawn PAR or propose to do so as ILS is extended. Special mention is made of the dependence of the decision on local conditions, and where military as well as civil aircraft are involved.

49 Having considered the replies from individual countries, ICAO suggests that the following two basic considerations emerge:

(i) the military services continue to consider PAR as a rather important part of their nagivation services provided for approach and landing purposes and, as a consequence, PAR facilities operated by the military at jointly-used aerodromes will be retained;

(ii) in all other cases where purely civil considerations prevail, the decision regarding retention or withdrawal of PAR facilities must be based primarily on local factors which vary considerably from location to location. Agreement on a generally acceptable policy which can be applied rigidly within the entire region appears, therefore, very difficult to obtain.

50 ICAO concludes from their enquiries that "Although no generally applicable principles can be retained regarding the use of PAR, it is the consensus of States and operators that the ILS remains the primary landing aid at international aerodromes and it would therefore appear that in all those cases where the decision to maintain or install a PAR is likely to adversely affect the performance of the ILS, be it due to dispersal of funds or manpower, priority should definitely be given to ensuring the highest possible standard of operation of the ILS concerned."

Other information on the views of foreign countries

51 To determine whether there has been any change of opinion since the date (May 1969) of the ICAO communication to the Board of Trade, we sought the current views of certain countries, and the replies to our enquiry are also reproduced in Appendix 7.

52 It will be seen that in Eire the support for PAR monitoring has, if anything, strengthened and that an additional installation will soon come into operation at Cork. The arguments cited in favour of PAR monitoring are those already mentioned in our report, but the economic argument is also advanced that one PAR can provide approach facilities to at least four different runways, and that to replace PAR completely at Irish airports would involve the installation of three additional ILS facilities at Dublin and Cork and two at Shannon.

53 West Germany continues to see advantages in PAR and operates or will operate facilities at the international airports of Hamburg, Dusseldorf, Hanover, Frankfurt, Cologne-Bonn, Stuttgart and Munich.

54 In their reply to ICAO, the French authorities expressed the opinion that decisions to withdraw or extend PAR facilities could not be based on a general principle, but required a detailed study of each problem raised in consultation with the airlines. They referred to the need for PAR monitoring where local topographical or meteorological conditions created special difficulties, and said that the existing aids at Bordeaux, Le Bourget, Strasburg, Orly and Tours were still in use. In the more recent letter, French opinion appears to have moved somewhat away from PAR, and we are informed that "France is no longer going to install PAR at her civil aerodromes". PAR is, however, to be retained at Le Bourget although it will be withdrawn from Orly following the installation of ILS on runway 25 at this airport.

55 The Netherlands authorities have not changed their views and feel no need for PAR monitoring at Schiphol airport. They also inform us that KLM is of the opinion that no PAR facilities are needed where ILS is available.

56 To explore opinions in the USA we held a discussion with Mr A B Johnson of the Federal Aviation

Administration. He began by reading a statement made by the FAA in connection with the Senate Aviation Sub-Committee Hearings. The statement represented current FAA policy on PAR and was as follows:

"Our policy is to provide PAR service at only those FAA tower airports where PARs are already established and there is a stated military requirement for it — formally verified by the Department of Defence. Over the past 5 years FAA, after careful study of PAR utilization and need, have decommissioned eighteen PARs because of very infrequent use of the service in IFR conditions. Only eight civil PARs are now being operated, and these are on a standby-on-request basis. After further review to confirm lack of use and need, the agency will probably phase some or all of the eight out of operation."

57 Mr Johnson went on to explain that, following evaluation trials, the United States Air Force had decided in favour of PAR for some military aerodromes because of their particular requirements for combat aircraft, but ILS was chosen as the primary approach aid for civil aircraft. Earlier experience with civil aviation had indicated that the PAR service was not extensively used.

58 It was the United States practice to use the voice channel on the localizer frequency when monitoring with PAR. This required the pilot to listen on a different frequency from the control frequency, and there were doubts that pilots tuned in to the PAR frequency. Acknowledgement from the pilot was not required during straightforward monitoring, and it was difficult to confirm that the service was being used. Despite this, the controllers continued with PAR whenever minimal weather conditions prevailed.

59 A survey carried out in 1966 revealed that the use of PAR was minimal except for practice. At about this time, the United States authorities decided to withdraw all but a few PARs for recalibration. When the equipment was returned to service, it was found that there was no increase in its use, and a further review in 1968 recommended that the PAR service should be discontinued at all but two locations. No provision for PAR was included in any new or proposed facilities.

60 The decommissioning process was halted following two accidents in December 1968, and eight PARs were left in standby-on-request service pending the outcome of a further review. We understand that since our meeting with Mr Johnson, it has been decided to withdraw these remaining installations.[2]

61 After our discussion with him Mr Johnson made available to us copies of the staff study reviews of 1966 and 1968 to which he had referred. These were not aimed wholly or, indeed, primarily at exploring the use of PAR to monitor ILS approaches, but deal with the broader question of the use of PAR not only for monitoring but also as the primary aid, and consider both military and civil usage. Data are included on the number of PAR monitored approaches, but not on the number of occasions in which intervention took place, the reasons for intervention, and whether the pilot responded to intervention. The surveys illustrate the point made by Mr Johnson about PAR usage. In the six-month period December 1967 to May 1968, PAR was used at eight primarily civil airports during on average 0·375 per cent of the total instrument approaches with only two airports (8·3 per cent and 1·1 per cent) departing appreciably from this average. Amongst the approaches using PAR, the installation was used for monitoring in on average roughly 0·2 per cent of total instrument landings.

British Air Line Pilots Association (BALPA)

62 At the beginning of our inquiry we were informed that BALPA had expressed the following opinion to the Board of Trade:

"Whilst it may be possible for other ground equipment to take over the monitoring function of PAR, such equipment is not yet generally installed. Furthermore, such equipment would not take into consideration any failure of aircraft equipment.

63 PAR is always valuable in providing a cross-check, which is entirely independent, during the late stages of an approach. If this monitoring function were taken into account, then PAR utilization could not be claimed to be low. Although the retention of PAR might be considered to be an expensive additional safeguard, an independent navigational facility to cross-check the path of an aircraft following the ILS is needed to meet the essential basic principle of navigation. A high proportion of accidents occur during the approach phase; the safety potential of PAR in this phase is evident if it is properly adapted to the monitoring role. The use of PAR should be retained, and equipment and operating practice improved rather than removed.

64 In view of the above, the Association is of the opinion that the decision to withdraw PAR from United Kingdom airfields was unwise and that it should be reversed. The Association further considers that pressure should be brought to bear internationally to emphasize the need for PAR as an independent cross-check facility and as a stand-by facility for use in the event of ILS failure."

---

[2] We have since been informed by Mr Johnson that an Order was issued in June 1970 authorizing the decommissioning and disposition of all FAA PAR facilities except those that will continue to be operated on the basis of military requirement. There are six such locations.

65 To secure further information, a discussion was held with Capt H A Hopkins of BALPA. He confirmed that BALPA had not changed its view. PAR was a cross-check providing an additional safeguard during the critical approach phase. Where being employed as a monitor, PAR became a second source of information, confirming the position of the aircraft in azimuth and elevation. He agreed that the majority of landings using ILS alone were good, but deviations from the glide path still occurred. Pilots and their aircraft were not always perfect and there were several reasons, eg misleading visual clues, malfunctioning instruments and inexperience which could give rise to poor approaches. PAR, under ground control, was independent of the aircraft and it was this factor which made it so successful as a monitor.

66 Apart from ILS, PAR was the only approach aid at present available and Captain Hopkins expressed the view that it should remain in operation until a suitable alternative was produced. In fact, BALPA would like to see an extension of its use. Discussing possible alternatives, Captain Hopkins agreed that DME was accurate enough but it was "passive" and, as a monitor, would need a comparator system with a read out in the aircraft.

67 ILS was, of course, the standard internationally approved approach aid. The USA had already withdrawn most of their PARs and the remaining eight would probably be phased out of operation. Captain Hopkins felt that if the United Kingdom also withdrew its PARs it would not be long before the rest of Europe did likewise.

International Federation of Air Line Pilots Associations (IFALPA)

68 In response to an enquiry about the views of his federation, the executive secretary informed us that IFALPA favour the use of PAR under the following conditions:

"Where other[3] precision radio aids such as Precision Approach Radar (PAR) are in use, they should operate to the same glide slope angle as is established for the ILS.

69 For the application of these requirements we visualize that the locations would be selected at the appropriate ICAO regional meeting according to the following guide lines:

(a) at high density traffic aerodromes;

(b) where parallel runways are in simultaneous use (eg London and Frankfurt);

(c) where the ILS beam is known to suffer regularly from instability (eg Genoa due terrain effects)."

Guild of Air Traffic Control Officers

70 The views of the Guild of Air Traffic Control Officers are given in a letter reproduced as Appendix 8. Attention is drawn to the fact that the high potential accuracy of PAR can be realized only if there is stringent adherence to the specified tolerances in calibrations and checks and if the controllers have regular practice. The point is made that practice is less essential in the monitoring role, but is essential if the operator is to take over and provide a full PAR approach.

71 Reference is made to the fact that Category II ILS is more prone to "tripping" than the Category I system and to errors produced by reflections and other radiations. New equipment is being developed to overcome such operational difficulties, but cannot be introduced without delay. Until the difficulties have been overcome there is a case for PAR monitoring although it is recognized that this will not necessarily reduce accident risks if deviations occur in the final stages of the approach because of the time lapse between controller recognition of the deviation and the pilot's reaction to the receipt of warning.

Air Registration Board (ARB)

72 The ARB was asked for its general views on the need to retain PAR as a monitor and also (because the question of operators' limits and weather minima is relevant to our inquiry) for its view on criteria which might be considered in establishing limits for landing for different types of aircraft at individual airfields. The ARB replied that they were little concerned with either question. Their responsibility in connection with approach was largely confined to the airworthiness of the airborne equipment and its suitability to achieve the safety desired with the ground equipment provided. So far in their work, no allowance had been made for the presence or otherwise of PAR.

73 ARB informed us that they were, of course, aware that neither equipment nor personnel are completely infallible and if it is decided that PAR can play a useful part in providing safety on the occurrence of equipment or human faults then ARB would be in favour of it where it can be economically justified.

74 On the question of limits for landing, ARB was concerned in its ordinary performance studies with landing distances in relation to aircraft weight, aerodrome slope, runway surface etc. It also stated the "decision height" as a limitation in the flight manuals

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[3] This follows a previous policy reference to ILS being the approved non-visual aid.

of aircraft equipped for low approaches and landing in all weather conditions. ARB is not responsible for the criteria at particular airfields which is contained in an operator's manual subject to Board of Trade supervision. The decision heights given in flight manuals have so far been determined solely from the aircraft's ability to hold an ILS beam accurately, to know its altitude accurately, and to overshoot safely from the decision height should the pilot decide to do so.

Air Safety Group

75 The Air Safety Group is a voluntary effort for the promotion of greater safety for air travellers. Its views were sought through its chairman, Mr Eric Lubbock. We were told that it was unlikely that a unanimous Group opinion could be provided, and were sent the views of individual members which are summarized below, together with the profession of the member concerned.

(i) Although PAR is less accurate than ILS, it is useful in providing an independent check that there is no *gross* deviation from the intended flight path especially in altitude (aeronautical engineer).

(ii) PAR may provide a check on whether another aircraft (not necessarily on approach) has entered the relevant airspace (aeronautical engineer).

(iii) The concensus of opinion amongst pilots that I have consulted is that PAR monitoring should be retained. It is agreed that control should be in the cockpit as far as possible and that ILS must be the primary landing aid. Continuous PAR monitoring in marginal conditions is, however, a comfort.

There are several instances of all the crew members on the flight deck mis-setting or misreading altimeters and the ensuing fatal result could be prevented by a radar controller with glide path information. PAR monitoring may be especially valuable in cases of emergency (aviation journalist).

(iv) PAR monitoring is a great safety back-up. It should be retained at two or three major airfields in the United Kingdom, eg Heathrow, where parallel landings may take place and two airfields used as "master" diversion airfields such as Manchester and one other (pilot).

(v) PAR monitoring is no longer justified on economic consideration. It is a luxury which pilots do not mind keeping as long as somebody else pays the bill (pilot).

(vi) As one whose work is closely associated with air safety, I was most concerned when it was decided to do away with PAR both as an aid and as a means of monitoring the ILS. PAR not only monitored the ILS equipment but also the manner in which a pilot flies the ILS. In the not too distant future automatic landings will be commonplace, the present RVR limitations will then no longer apply and it will be vital to monitor the ILS.

To my knowledge at least three accidents could have been avoided by PAR monitoring, and others may have been prevented by advice from PAR monitoring. I have asked many pilots for their views and almost to a man they favour PAR monitoring.

PAR is, if nothing else, a safety measure and as such should be retained. It may be costly, but it is nothing like as costly as that other safety measure, the airfield fire service, yet no one has ever mentioned disposing of the AFS on the grounds of expense.

It is interesting to note that although PAR is no longer at Gatwick, the old Federal GCA is in use to monitor aircraft in elevation, not in connection with safety but noise violation! (air traffic controller).

(vii) Precision approach radar should be retained or installed at all major airports. It provides added safety as a back-up or alternative to ILS. Airborne equipment does not always "fail safe"; failure flags may not appear if the signal output is of sufficient strength and the receiver in the aircraft working normally despite the fact that the deviation comparator has ceased to function. The central indication in the aircraft would, in these circumstances, be misleading and dangerous.

Without adequate height finding equipment at and in the vicinity of airports, PAR is the only means of providing height data, at least on the approach path; in many instances it has enabled aircraft to be turned away from a previously unknown hazard. Until such time as proper airspace restrictions are imposed to prevent unknown aircraft from endangering inbound and outbound traffic, PAR provides at least some means of collision avoidance.

Poor weather conditions are known to affect ILS installations to the extent that critical bends occur during the final stages of an approach. These cannot be flight checked because they disappear in good weather.

Modern jets use vast quantities of fuel at low levels and PAR monitoring or, if necessary, a full PAR approach may prevent unnecessary overshoots and diversions. This would save time and money for the operators and reduce the mental strain on all concerned. The easing of congestion of the already overcrowded airspace would make an all-round contribution to safety.

With the great number of large jet aircraft in use at present and those to come in the future, any safeguards already in existence should certainly not be withdrawn to cut expenditure on air traffic control (pilot).

Board of Trade

76 Representatives of the Board of Trade informed us that, following the adoption of ILS as the standard international approach aid and its installation at United Kingdom civil airports, it gradually replaced PAR as the primary approach aid for civil aircraft. ILS was more accurate and PAR was therefore rarely used. When in 1966 it became apparent that provision would soon have to be made for replacement of the existing equipment, the National Air Traffic Control Services carried out a review of the need to retain PAR, after which it was decided that the existing installations should be progressively withdrawn and to make no provision for replacement. In addition to the decline in the use of PAR, consideration was also given to the high capital cost of replacement, the high annual operating costs, and the difficulty of finding staff to man the equipment. There was also a lack of international support for PAR, and ICAO policy did not require it, except in certain conditions which did not exist in the United Kingdom.

77 We asked the Board of Trade whether they had had any reason to reconsider their decision and were informed that circumstances had not changed and the Board did not see any cause to amend their previous views. The reported findings of the DORA and Dutch studies of aircraft approaches which had been made since the earlier review had been closely examined but they were inconclusive; in the absence of adequate debriefing it was difficult to determine the reasons for the small proportion of ILS landings in which there had been significant departures from the normal approach path.

78 If deviations from the glide path occurred because pilots sometimes use ILS inadequately, the remedy should lie in improved training or more rigid regulations and not in providing an independent monitoring system.

CHAPTER 3

Evidence from operational experience

79 In parallel with securing the opinions of the organizations and individuals summarized in Chapter 2 of this report, we have examined the results of operational experience relevant to our inquiry. Because ILS is the internationally accepted approach aid, and we are concerned only with the use of PAR as a monitoring system, it is inevitable, as we have explained previously, that we should be particularly concerned with the accuracy and reliability of ILS approaches. The main sources of information on this matter come from cases where independent monitoring enables the accuracy of ILS approaches to be judged, and from reports of accidents that have occurred during or after ILS approaches.

Lock-follow radar monitoring by the Directorate of Operational Research and Analysis (DORA)

80 DORA have measured the flight paths of some two hundred ILS landings made at Heathrow in conditions of poor visibility using an X-band lock-follow radar. The measurements were made during the autumn of 1968 and the winter period 1968/69, and followed measurements of fair-weather approaches by means of a camera system. From our discussions with DORA it appeared that abnormally large deviations from the ILS glide path occur in a small proportion of approaches and, following our discussion, DORA have provided a brief note on this and other conclusions of their investigations which is reproduced as Appendix 9.

81 We note that the DORA observation that large deviations sometimes occur is supported by an independent investigation conducted by the National Aerospace Laboratory (NLR) at Schiphol airport. The report[4] of the NLR study discusses only two of these cases. In the first, the aircraft approached well below the glide path and an attempted correction shortly before becoming visual resulted in an unstable pitch control with path angles of $\pm 2\frac{1}{2}°$ around the glide path; recovery was apparently made by visual reference. In the second case discussed in the report, the aircraft made a steep descent due to a false fly-down indication of the error pointer; recovery was effected visually. The cause was a malfunction of the glide path receiver, and according to the pilot the flag arm remained inoperative. The report concludes that this example emphasizes the need for adequate protection against instrument failure in all phases of the approach.

82 Apart from this case, the reasons for the occasional large deviations from the ILS glide path remain uncertain although we have sought explanations from several sources. It may be, of course, that the pilot is often well aware that the deviations are present, and there is certainly no firm evidence that they correspond to potentially dangerous situations. On the other hand, when large deviations are observed by monitoring, it would seem important to determine why they occurred in case they reveal faults in the ILS system or its interpretation. Such information could only be obtained from the pilot after the aircraft has landed, and we recommend that efforts by DORA to secure this information be supported.

83 The fact that there is no record of intervention by PAR controllers during approaches where DORA observed departures from the ILS glide paths arises simply because no intervention actions were noted down in the ATC log books at that time, although the dates and periods when PAR was used for monitoring approaches were recorded. In addition to providing advice to the pilot PAR can, however, give useful evidence on malfunctions or misinterpretation of ILS equipment. We therefore, also recommend that if PAR monitoring is retained logs should be kept of at least the major deviations from the ILS glide path, and that efforts to secure information from pilots on their causes should be intensified. Pilots associations favour the retention of PAR monitoring (at least for certain airports), and should be willing to cooperate in this way.

PAR monitor logs

84 Although PAR is potentially less accurate than ILS, it enables departures from the ILS glide path to be detected especially if they are large. Operational experience of PAR monitoring with the remaining installations is, therefore, valuable in providing additional data on the accuracy and reliability of ILS

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[4] *Results of the Approach Path Measuring Program by Radar at Schiphol Airport during the winter 1966–67*, J M H van Vlaenderen, Report NLR TR 68096U, National Aerospace Laboratory, The Netherlands, 1968.

approaches. It seemed desirable to use up-to-date information[5] for this purpose in order to indicate the situation for current aircraft types, ILS systems, and personnel training. It also seemed important as discussed above to explain where possible the reasons for any major deviations that are observed.

85 We accordingly requested the ATC authorities at Heathrow and Manchester to provide logs of PAR usage, and encouraged DORA to seek comments from operators in cases where PAR assistance was provided. A copy of the letter sent by DORA to operators is reproduced as Appendix 10.

86 During the five-month period from August to December 1969, PAR monitoring was used during 1270 landings at Heathrow. At Manchester 166 landings were monitored in the three-month period October to December 1969. The PAR operator gave advice in forty landings at Heathrow and fifty-two landings at Manchester; these figures represent 3·14 per cent and 31·3 per cent of the total numbers of monitored landings at the two airports respectively. The relatively high figures for Manchester may result in part from the fact that pressure of work at Heathrow prevents operators from recording minor PAR advice on corrections. We were also informed that the Manchester 29 ILS is known to bend north in certain weather conditions, and the glide slope (although remaining within the specified tolerances) increases elevation in heavy rain or snow.

87 A study of the PAR logs shows that in most cases the advice given involved only minor corrections (eg 1° or 2° corrections) but the following extracts show that this is not always the case.

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[5] This was also necessary because detailed information on PAR monitoring for earlier periods was not available to us.

Extracts from PAR logs at Heathrow

Date	*Weather conditions*	*Remarks*
25.8.69	Cloud — 4/8 at 200 ft 8/8 at 350 ft Met. visibility — 1500 m RVR — ?	Heavy aircraft, fast speed, did not settle on ILS, crossed and recrossed localizer course. Advised at 2 miles, slightly left (250 ft) and closing, but went through and overshoot was advised at 1 mile when aircraft was WRC (approximately 500 ft). Glide path OK from about 4 miles, was higher to begin with.
15.9.69		Information passed 200 ft right at 2 miles then 100 ft right at 1 mile at which time aircraft was visual.
17.9.69	Cloud — 5/8 at 200 ft Met. visibility — 1300 m RVR — ?	200 ft right at 2 miles, 100 ft high. Then visual.
24.9.69	Cloud — 8/8 at 200 ft Met. visibility — 1500 m RVR — ?	200–300 ft above glide path from 5 miles. Instructed to overshoot at 1½ miles.
10.10.69	RVR — 900 m to 1000 m	200 ft right at 2 miles. Corrected immediately advice passed.
14.10.69		(i) Informed high on glide path at 1¼ miles. (ii) Settled 250 ft low on glide path then, after being told and QFE passed, 100 ft low. Thereafter aircraft flew one dot high and was on glide path when visual with VASIS. Aircraft instruments will be checked. (iii) 100 ft low at 1¼ miles. Informed and corrected. (iv) 100 ft left at 2 miles, 200 ft left at 1½ miles. Then visual correction.
17.10.69		(i) At ¾ mile advised turn 5° right. Captain telephoned after landing to say advice was much appreciated as a back up. He soon became visual and knew where to look for the runway centreline. (ii) Advised 3° right at ¾ mile then slightly left. Pilot reacted immediately.
20.10.69	RVR — 1000 m	Deviated 150 ft at 1½ miles. Informed and corrected.
21.10.69		(i) Seven aircraft landing in a two-hour period all deviated slightly left ½ mile from touch-down due to offset localizer and advisory correction given. (ii) Aircraft approached and landed when RVR was 200–350 ft and was advised of BOT limitations for transport aircraft. At 1½ miles was 150 ft below the glide path and shortly afterwards was instructed to maintain height. Deviated well left of track on three occasions and corrections given. Pilot said he saw approach lights although this was not consistent with action taken.
1.12.69		250 ft right at 2½ miles. Advised. Reason auto-pilot unlocked. Completed approach manually.

Extracts from PAR logs at Heathrow — *continued*

Date	*Weather conditions*	*Remarks*
6.12.69		Diversion from another airport. Full PAR. Aircraft not receiving localizer.
10.12.69	RVR — 300 m	(i) Diverged to left at 3 miles. Required corrections in azimuth to 1 mile. Five corrections given. Aircraft put on centreline. The pilot reported that the landing would not have been possible without PAR assistance because the localizer indicator was over-sensitive and impossible to follow. He expressed great faith in PAR. (ii) Required correction in azimuth and elevation from 3–1 mile. (iii) Had to take over and give full PAR from 3½ miles as divergence from centreline became dangerous. (iv) As above. Could not continue a satisfactory ILS approach. Full PAR needed. Very dangerous.
13.12.69		Aircraft was 180 ft left of centreline at 1¾ miles. Pilot informed. At 1¼ miles still about 180 ft left. I, therefore, advised the pilot to turn right 3°. The final approach track was then made good. One advisory intervention only. Pilot's comments: A useful correction. Smith's system gave no demand at the time although such a correction could have been expected at a later stage from the aircraft system. It would, therefore, have been a more violent turn and the final approach track regained at a correspondingly later point.
20.12.69	Cloud — 6/8 at 100 ft RVR — 600 m	Deviated 400 ft left at 4½ miles. Advised. Continued to go left (700 ft). Advised turn 10° right. Advised that aircraft was closing centreline and on centreline at 2½ miles. Deviated again at 1½ miles (300 ft). Instructed to overshoot. Pilot advised discrepancies on both Rx and further auto-pilot trouble.
27.12.69		Well left of track (max 600 ft at 2½ miles). Two 10° turns to right followed by one 10° turn to left then aircraft visual. Pilot advised automatic failed and reverted to manual.
26.1.70		200 ft low at 4 miles, 200 ft high at 2 miles, 150 ft high at 1 mile, 100 ft high at ½ mile, then visual.

Extracts from PAR logs at Manchester

Date	*Weather conditions*	*Remarks*
22.10.69	Met. visibility — 1000 m	Aircraft 100 ft right at 3 miles advised 10° turn left. 500 ft left at 2 miles advised 10° turn right. 200 ft left at 1½ miles advised 5° turn right. 100 ft right at 1 mile advised 5° turn left.
25.10.69	Cloud — 5/8 at 200 ft 8/8 at 500 ft Met. visibility — 1500 m	Aircraft flew left at 1½ miles. 6° correction. If not corrected aircraft would have had to overshoot.
3.11.69	Cloud — 6/8 at 200 ft 5/8 at 300 ft	(i) Aircraft 200 ft right at ¾ mile advised 5° turn left. (ii) Aircraft glide path failed. Given descent by PAR.
15.11.69	Cloud — 3/8 at 400 ft 8/8 at 700 ft	Aircraft 1000 ft right at 5½ miles going right. Advised 10° left turn. 500 ft right at 4½ miles, closing. Advised 5° turn right, and further 5° turn at 4 miles. Gyro error suspected.
1.12.69	Cloud — 3/8 at 100 ft 6/8 at 200 ft Met. visibility — 1800 m	(i) Aircraft 100 ft high 200 ft right at 3 miles. Autopilot disengagement. Aircraft overshot.
	Cloud — 3/8 at 400 ft 8/8 at 600 ft Met. visibility — 1600 m	(ii) 200 ft right 50 ft high at 2½ miles. Advised and corrected.
	Cloud — 8/8 at 200 ft Met. visibility — 2200 m	(iii) 100 ft right at 1½ miles. Advice given at 1½ and 1 mile.
2.12.69	Cloud — 8/8 at 200 ft Met. visibility — 1900 m	(i) 350 ft left at 1½ miles. Pilot informed left and going left and almost immediately reclosed the centreline.
	Cloud — 2/8 at 100 ft 5/8 at 200 ft Met. visibility — 1600 m	(ii) 1500 ft left at 4 miles. Advised to turn 5° right to close centreline.
	As for (ii)	(iii) 200 ft left at 2½ miles through centreline to 200 ft right at 2 miles. Corrections advised and taken.
	As for (ii)	(iv) 200 ft right at 2 miles. Corrections advised and taken.
7.12.69	Cloud — 6/8 at 200 ft 8/8 at 4000 ft Met. visibility — 1500 m	250 ft right at 2 miles. There was an obvious wind change on descent, and after intervention aircraft corrected fairly quickly for the drift to the right.

Extracts from PAR logs at Manchester — *continued*

Date	*Weather conditions*	*Remarks*
12.12.69	RVR — 700 m	100 ft high at 5 miles, 300 ft at 4 miles where weave developed. Advised and decreasing corrections taken. The pilot reported as follows: "I was using the zero reader to do an ILS approach which means that it is quite possible to go through the centreline in the first interception. Radar gave me 500 yards south after I had made a correcting turn, then '500 yards north'. This enabled me to come to the conclusion that the zero reader was not working correctly, but a further call from radar that I was 'approaching the centreline' make it possible for me to be back on track very quickly. A normal ILS was then made. Had radar not intervened, it might have taken longer to get back on the centreline, but I am sure a successful approach could have been made. However, it is always comforting to have a second opinion, and the help was appreciated."
19.12.69	Snow Met. visibility — 1200 m RVR — 1000 m	600 ft right at 3½ miles. Advised 4° left turn at 3½ miles, 4° right at 3 miles and 3° left at 2 miles. Reported fluctuating localizer.
23.12.69	Cloud — 5/8 at 100 ft 8/8 at 500 ft Met. visibility — 1500 m	(i) Aircraft 100 ft right all the way in to ¾ mile then told. Immediately moved to centreline but this could have been because pilot saw lights.
	As for (i)	(ii) Aircraft paralleling 500 ft left until informed at 2½ miles.
24.12.69		(i) 160 ft left at 1½ miles. Advised turn 5° right. (ii) At 1½ miles 50 ft low and descending, and 100 ft right and going right. Advised overshoot. Aircraft overshot and diverted to another airport.
18.1.70	Fog Cloud — 7/8 at 100 ft Met. visibility — 600 m	(i) Aircraft 150–200 ft right warned at 2 miles "slightly right", at 1½ miles and 1 mile "still right of centreline". Pilot made little adjustment to heading in response to warnings, but overshot after the last intervention.
	Fog Sky clear Met. visibility — 800 m	(ii) Same aircraft 100–200 ft right. Warned at 2 miles "slightly right", at 1½ miles and 1 mile "slightly right". Pilot adjusted heading on information given by PAR and landed successfully.

88 Pilots' comments, where available, are included in the log extracts, but we have also one pilot account of PAR assistance during a landing at Heathrow for which the PAR log is not available to us. This reads as follows:

"Coupled up well left of centreline and beam appeared immediately. F/O uncoupled and recoupled and beam again appeared. Aircraft turned onto 105°. At 2° deflection glide path coming in. Height lock disengaged and glide slope followed on pitch wheel. No centreline closure.

PAR then gave us a heading change to 140° to close 'due to strong southerly wind'. Uncoupled, turned onto 140°, closed with localizer and recoupled.

PAR was very quick to see our failure to close. Had we not had PAR monitoring at London Airport we would not have descended on glide path whilst still off localizer, and by the time we had gained the centreline we would have been very high on the glide slope."

89 It appears from the logs that there were seven cases of airborne instrumentation failures at Heathrow and three at Manchester during the periods considered above. In two other cases at Heathrow the PAR operator had, for reasons not known, to take over the approach and in seven cases he had to advise small corrections because of an offset localizer. It is, of course, impossible to conclude whether a potentially dangerous situation would have resulted if PAR monitoring had not been available, but there are several examples where, without it, overshoots would probably have occurred.

90 An additional example of the failure of ILS ground equipment was experienced personally by one of us (M H Barrett) during the course of our inquiry. "After a long night duty (14¾ hours) on a flight to Nicosia and back, including a diversion to Paris, I returned to Gatwick in poor weather conditions on the morning of 14 May 1970. I was positioned towards runway 09 and told that only the ILS glide path was serviceable. Without runway alignment my landing limits were raised from 250 to 550 feet. I continued to this higher limit and then overshot to Mayfield (the local holding beacon).

91 I requested the 27 ILS for an approach, but was

told that this was unserviceable and, having fuel available, I decided to wait in the hope that the weather would improve. After about 15 minutes, control informed me that the 27 ILS was expected to become serviceable again, and radar positioned me for an approach. After a further short delay the ILS became serviceable, and an approach and landing were completed.

92 No statement had been issued concerning the unserviceability of the ILS. When I enquired from control at Gatwick I was informed that the temporary offset localizer on runway 09 failed to start after a runway change, and that a quick changeover could not be guaranteed until the main ILS transmitter returned to use in July.

93 I consider that a pilot who returns to a major airport after a long duty could reasonably expect better ground facilities than were available on this occasion. If such unserviceability can occur so easily with the inevitable rapid build-up of traffic, there may be a case for installing a reliable independent approach aid such as PAR that is not affected by local repair work."

Accident reports

94 Tables have been prepared from summaries of accident reports and from details supplied by the Board of Trade on significant incidents. Incidents do not have to be reported, and the tables may be incomplete. The accident reports show that in the period 1960–69 there were some sixty-seven world accidents (excluding the USSR etc) to transport aircraft during or after approaches made with ILS, but only those appearing relevant to our inquiry are listed here. So far as is known, PAR monitoring was not used in the cases listed in Table 1, but it appears to have been used for those listed in Table 2.

ILS approaches without PAR monitoring

95 Of the accidents or incidents in Table 1, nineteen involved errors in altitude, three in azimuth, and three in both altitude and azimuth. Where the causes are stated in accident reports, improper ILS approaches are mentioned in eight cases.

96 We have thought it necessary to give here brief descriptions of a selection of the accidents, especially those involving United Kingdom aircraft or airports, in order to illustrate some of the hazards that may arise during or following ILS approaches. It is, of course, very difficult to judge whether PAR monitoring might have prevented some of the accidents or incidents and, unless there is a statement to the contrary, any comments on this matter are our personal impressions and do not refer to conclusions of the official accident reports.

(*i*) *Viscount of Turkish Airlines Incorporated near Gatwick Airport, 17 February 1959*[6]

This is an early example of an accident after an ILS approach, and attracted considerable publicity because the aircraft was carrying the Turkish Prime Minister, M Menderes. The aircraft was on a special flight from Ankara to London via Rome. Shortly before it arrived in the holding pattern for London Airport, London Airways passed a message directing it to proceed to Gatwick. Gatwick ATC then took over the control of the aircraft and radar positioned it for a final ILS approach. During its approach to land the aircraft crashed in a wood obscured by fog 3 miles from the threshold of the runway. The aircraft was destroyed and of the twenty-four occupants, fourteen were killed and nine injured. The following excerpts from the accident report summarize the relevant history of the flight:

"At 1621 hours the aircraft reported over the Epsom range and asked for and was given diversion instructions. At 1627 hours it left Epsom for Mayfield, the holding point for Gatwick, where it was informed by Gatwick Approach Control that it would be positioned by radar for an ILS approach to runway 09. To this the aircraft replied 'thank you'. The latest weather report for Gatwick was given as wind calm, visibility 1·1 nautical miles, mist, cloud 3 oktas at 800 feet, QFE 1036 mb. Radar Director 1 operating No. 1 Plan Position Indicator (PPI) identified TC-SEV over Mayfield NDB at 4000 feet and instructed it to steer a course of 280° and descend to 2000 feet. This was acknowledged. The aircraft was then told to change radio frequency to that of Gatwick (Radar) Director 2. The communications on this frequency were not electronically recorded . . ."

"According to the recollections of Director 2, clearance was given for a descent to 1500 feet on a QFE of 1036 mb. What appeared to be a normal radar positioning was carried out, the aircraft overshooting the centreline slightly as it turned onto the ILS approach path. At 5½ nautical miles from touchdown, in reply to a query from Director 2, the aircraft affirmed that it could continue on the ILS. TC-SEV was then asked to change to tower frequency and this request was acknowledged. This was the last communication with the aircraft . . ."

"The blip representing the aircraft continued along the approach path centreline on the radar screen towards the runway until it faded and disappeared

[6] *Report of the Accidents Investigation Branch*, Ministry of Aviation, December 1959.

about 3½ nautical miles from the threshold. Radio calls to the aircraft brought no reply and it was assumed that an accident had occurred . . ."

"In an attempt to establish the track of the aircraft after it left Mayfield beacon a widespread search for eye-witnesses was carried out. No one was found who could testify to having seen the aircraft. While this was no doubt due to the weather conditions prevailing at the time of the accident a considerable number of persons interviewed heard an aircraft flying — most say very much lower than normal — in their vicinity. Circumstantially, it is believed that this aircraft was the Turkish Viscount . . ."

"It has not been possible to establish what the aircraft's manoeuvres in altitude were during the concluding stage of the flight. The radar equipment (PPI) in use at the time does not provide height information . . . Survivors have said that no unusual occurrences or manoeuvres took place, and that none of the crew appeared to be disturbed or in any way apprehensive. The evidence indicates that the aircraft was under the control of the crew when the accident occurred. Several hypotheses as to how the pilot may have been misled by false radio signals or indicators, or by sensory illusions resulting from the appearance of a light or lights in the fog have been explored; no evidence to support any of these theories was discovered.

During discussions with the Turkish Technical Delegation about the use and availability of radio aids in Turkey, it transpired that the captain may have been using the ADF equipment as his primary approach aid. Whatever aid he was using, it seems clear that the final approach to land was not related to the ILS glide path, and it may be that pilots flying in a foreign country over unfamiliar terrain and confronted with a diversionary landing in poor weather conditions became involved in a task which was beyond their training and experience."

The accident report notes that there was no malfunctioning of the aircraft or its engines or the ground facilities. Nevertheless, the aircraft crashed into the tops of trees 390 feet above sea level at a point approximately 3 nautical miles from the runway threshold and 550 feet off the centreline. There is circumstantial evidence that the aircraft had been flying considerably below the normal height of aircraft approaching the airport, and it seems possible that this would have been detected if the GCA equipment at Gatwick had been in use at the time. Although we cannot say what action the pilot would have taken in response to warning from the GCA operator or whether there would have been time for his action to be effective, it seems possible that the accident might have been prevented.

(ii) *Viking of Cunard Eagle Airways near Stavanger Airport, Sola, Norway, 9 August 1961*[7]

Very large errors in the flight path have sometimes occurred during ILS approaches, and this early example led to especially tragic results because the aircraft was carrying a party of school children. The aircraft was on a flight from London to Stavanger and crashed into a mountainside about 18 miles from its intended destination. The aircraft was destroyed and the thirty-six passengers and three crew members were killed.

The accident report states that the captain attempted to carry out an ILS approach to Stavanger, but diverged from the prescribed flight path for reasons unknown. The most likely reason is considered to be associated with the very strong south-westerly wind. It was established that the aircraft passed the vicinity of Sola northbound, and it is reasonable to assume that the captain was attempting to follow the prescribed ILS procedure. It is likely that the wind at 1600 feet was about 230°/60 knots and the maximum drift the aircraft would experience on the procedure turn would have been about 26°, and during part of the turn the ground speed may have been as high as 193 knots. If insufficient allowance was made for the drift, it can be shown that by the time the aircraft had completed the turn to regain the localizer beam the wind effect would have taken it close to or even through the centreline. After completing this turn, the aircraft should still have had a short distance to run before reaching the beam and at this point the localizer needle on the instrument in the cockpit should be giving a "fly-left" indication. When this needle starts to move towards the "on course" position the turn onto the final approach is made. However, if the aircraft had passed through the centreline whilst still making the turn, the crew ought to have been aware of this from the "fly-right" indications even if they had missed the actual movement of the localizer needle. In addition, the radio compass indicator would have made this apparent if it were correctly tuned.

After completing the procedure turn there is little doubt the crew expected still to be on the western side of the localizer beam, and they may have missed the movement of the localizer needle that resulted from crossing the beam. If the crew misinterpreted the indications of the localizer needle, this would help to explain why the heading of 135°–140° M was maintained to the position of the crash. However, if the ILS equipment in the aircraft was working satisfactorily the crew must, for at least 4–5 minutes, have had a continuous indication that they were on the eastern side of the localizer beam. The accident report is unable to explain how the crew could continue on the heading indicated for the time stated unless they either did not note or were misinterpreting the ILS indicator readings.

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[7] Report of Royal Norwegian Commission, CAP 182, HMSO, 1962.

This example is included to show that errors have probably occurred in ILS landing in assessing on which side of the localizer beam the aircraft is situated, and that these errors have apparently remained undetected for a long period. The deviations from the ILS path were so gross that almost any radar monitoring system would have detected them. PAR (GCA) was available at Sola at 45 minutes notice, but was not in use at the time of the accident.

The accident report concludes that the non-employment of PAR could not be termed a contributing cause of the accident, but goes on to say:

"Nevertheless, the general standard of flight safety at airfields would, of course, be enhanced by the use of radar surveillance at all times. Thus the Commission is inclined to believe that the accident might have been avoided if the GCA station had been utilized either in its primary function or for surveillance. The latter utilization of the equipment would have enabled the ATC officer to initiate corrective action as soon as the radar scope information showed that the aircraft was astray."

(*iii*) *Viscount of British European Airways at Berlin (Tegel), 17 March 1963*[8]

At the conclusion of a flight from Hanover, the aircraft diverted from Tempelhof after two unsuccessful attempts to land there because of inadequate visual reference to the ground. At Tegel an ILS approach was made down to 400 feet when the approach lights were sighted, and was then continued solely by visual reference.

The approach and runway lighting was being modified, and this involved displacing the threshold of the runway by some 900 feet but, because Tegel was a military aerodrome, the pilot had not been informed of this change. The aircraft touched down short of the runway, the nose wheel collapsed, and the aircraft sustained substantial damage. Nobody was injured.

PAR monitoring might have prevented the accident, although it may be that the controller would have become aware of the captain's ignorance of the displaced runway threshold too late to give useful advice.

(*iv*) *Lockheed Super Constellation of Iberia Air Lines at Gatwick Airport, 2 September 1963*[9]

During the approach to landing the aircraft brushed the trees on Russ Hill about 220 feet above and 1¾ nautical miles from the runway threshold. The aircraft was slightly damaged, but there was no injury to the passengers or crew and a safe landing was made.

When the aircraft was on base leg flying at 2000 feet the pilot asked Gatwick whether the glide path transmitter of the ILS was working properly and, on being given an affirmative reply, he informed the controller that the glide path equipment in the aircraft was inoperative. The controller cleared the aircraft to descend to 1500 feet, and advised the pilot to turn on to the ILS localizer. The localizer was intercepted at a range of 6 miles, after which the pilot was cleared to descend to 1000 feet and cleared to land. After the pilot reported over the outer marker, the controller cleared the aircraft to descend to critical height. He also informed the pilot that the obstacle clearance limit was 470 feet, and added that there were 4½ miles to go. As the aircraft crossed Russ Hill it brushed through the tops of trees.

The captain stated that the company minima for this flight were a critical height of 250 feet and a runway visual range of 1 mile, but because there was no glide path available his "personal" critical height was 400 feet. This was greater than the OCL of 290 feet with localizer only, but to ensure a safe approach when glide path information is not available, regard must also be given to the procedure notified in the air pilot for this type of approach; this requires a minimum height of 490 feet above aerodrome level to be maintained at the middle marker. The operations manual made no reference to this.

The accident report concludes that the approach must have been continued without visual reference to the ground well below the critical height of 400 feet which the captain had set himself, and also below the critical height of 250 feet laid down by the operator for a normal ILS approach.

Precision Approach Radar was available at Gatwick at the time of the accident, and could be brought into operation within 10 minutes if requested. After the accident the captain stated that he believed that the aircraft was being monitored on radar in both azimuth and elevation during the approach. The accident report states that it would have been good airmanship on the part of the captain to request PAR monitoring when he became aware that his ILS glide path receiver was unserviceable. The report also suggests that although primary responsibility for initiating the use of PAR lay with the captain, the controller might reasonably have reminded him of its availability.

We conclude that PAR monitoring might have prevented the accident, and we note that when PAR is available the report illustrates a potential danger in not using it as part of the routine procedure for ILS landings in poor weather because, at least in this example, confusion may otherwise occur about whether PAR monitoring is in use. Although only minor damage resulted from the accident, the consequences might have been extremely serious because over eighty passengers and crew were in the aircraft.

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[8] *A Survey of the Accidents to Aircraft of the United Kingdom in the year ended 31st December, 1963*, CAP 211, HMSO, 1964.
[9] Report of the Accident, CAP 218, HMSO, 1964.

(*v*) *Aircraft DC4 G-ASOG of Air Ferry Ltd at Frankfurt 21 January 1967*[10]

In some cases errors in altimeter settings have apparently contributed to accidents during ILS approaches, and an example is summarized here. Following an uneventful flight from Manchester the aircraft struck trees 10 metres high when 2700 metres from the threshold of the runway at Frankfurt and 100 metres left of the ILS centreline. The aircraft and its cargo were destroyed and both pilots (the only occupants of the aircraft) were killed. Some 5 minutes before the accident the aircraft was cleared by Frankfurt approach control for an ILS approach, and about 3 minutes before the accident it was on its final approach 8 miles from the airport. Navigation surveillance radar, which was used solely for traffic guidance and indicating the track of the ILS localizer, was serviceable at the time of the accident. Precision Approach Radar was not operating.

The accident investigation showed that the weather conditions on the approach made no special demands on the ability and operational efficiency of the crew, and that no technical defects could be found in the aircraft or engines. It was also concluded that defects in the approach or runway lighting could not have led to the accident. On days other than that of the accident, pilots had reported fluctuations in the ILS glide path installation, but two calibration flights after the accident showed that the ILS was working within the permissible tolerances. This was confirmed by a pilot who made a landing immediately after the accident, and three other pilots who landed shortly before or after the accident. Nevertheless, the accident investigation concludes that a brief fluctuation of the ILS glide path system within permissible balances cannot be excluded at the time of the accident. Such a brief fluctuation produces a change in the indicator reading which is disquieting for the pilot, and would demand such an abnormally abrupt change of flight path that it is hardly to be expected that such a reading would be acted upon. Even taking this possibility into account, however, the aircraft should not have descended below the critical height because the pilot is required by the regulations not to descend below this height in any circumstances without visual reference.

The accident report concludes that the descent considerably below the critical height, and the consequent collision with trees, can only be attributed to an error on the part of the crew. The report notes that the accident might have been prevented if the aircraft landing lights had been switched on earlier, but points out that there is no regulation governing the time of switching on the lights or any compelling reason why the crew should have done so at the relevant stage of the approach.

It is considered that because of the good weather conditions encountered early in the approach, a visual approach was begun at a substantial distance (5 miles) from the runway, and that the crew were concentrating on the impending landing using the altimeters alone as aids to checking the flight path. The accident report concludes that the accident is probably attributable to the fact that the crew did not set the altimeters in the final approach according to the operations manual, and notes that this error was aggravated by the fact that the final approach check list did not coincide with the altimeter setting procedure. As a result of the error the crew unintentionally flew below the critical height, and the aircraft collided with trees when the altimeter was showing approximately 200 feet above the critical height.

The accident report makes no mention of the contribution that PAR monitoring might have made to avoiding the accident. The aircraft was, however, considerably below the ILS glide path at a substantial distance from the runway and we feel that PAR monitoring might have prevented the accident if the pilots had acted promptly on warning from the PAR operator.

(*vi*) *Boeing 727 of Ariana Afghan Airways near Gatwick, 5 January 1969*[11]

Some of the examples described above occurred several years ago, and it might be argued that improved procedures or equipment would today preclude the large deviations from the ILS glide path that sometimes evidently occurred. This recent accident is, therefore, especially relevant to our inquiry, and sections of the accident report are reproduced below.

"The accident occurred on a scheduled passenger flight from Frankfurt when the aircraft was making an ILS approach for a night landing on runway 27 at Gatwick Airport. The weather was clear except that freezing fog persisted in places including the Gatwick area. The Runway Visual Range (RVR) at Gatwick was 100 metres. The approach was commenced with the autopilot coupled to the Instrument Landing System (ILS) but after the glide slope had been captured, the commander, who was at the controls, disconnected the autopilot because the 'stabilizer out of trim' warning light illuminated. At the outer marker the flap setting was changed from 15° to 30°, and shortly afterwards the rate of descent increased and the aircraft descended below the glide slope. Some 200 feet from the ground the pilot realized that the aircraft was too low and initiated a missed approach procedure. The aircraft began to respond, but the descent was not arrested in time to avoid a collision with trees and a house that destroyed both the aircraft and the house and set the wreckage on fire. The report concludes that the accident was the result of the commander inadvertently allowing the aircraft to descend below the glide slope during an approach to land until it was too low for recovery to be effected." As a result of the accident fifty people were killed and fifteen seriously injured.

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[10] Report of the Accident, CAP 310, HMSO, 1968.

[11] Report of the Accident, CAP 344, HMSO, 1970.

To understand the potential contribution of PAR monitoring it is necessary to summarize the history of the flight, especially during the approach. The aircraft was on a scheduled flight from Kabul and a fresh crew took over at Beirut. They made routine landings at Istanbul and Frankfurt except that at Frankfurt the "stabilizer out of trim" warning light illuminated during an ILS coupled approach. The first officer, who was at the controls, disconnected the automatic pilot, trimmed the aircraft longitudinally to relieve the pressure on the control column and made a normal manual landing.

During the flight to Gatwick, the RVR there was verified as 100 metres and the captain confirmed his intention to attempt a landing. The crew began their approach checks. The pressure altimeters were set to QNH and cross-checked; the operator's weather minima applicable to Gatwick of 200 feet critical height (the height to which the commander was permitted to make an approach without visual reference to the ground) and ½ mile RVR were checked and the cursors on the radio altimeter were set to 200 feet on the port side and to 500 feet on the starboard. The compass heading cursor was set in preparation for a go-around (missed approach) and the commander told ATC that in this event he would proceed to Mayfield and then to Heathrow. ATC then gave the aircraft a heading to close with the ILS localizer and then distances from touchdown of 13 miles and 11 miles. During the turn on to this heading the commander, who was at the controls, coupled the automatic pilot to the ILS, selected the "glide slope auto" mode on the flight director and the autopilot selector boxes and switched on both altitude holds to hold 2000 feet. The co-pilot's flight director was left switched off so that only the basic ILS indications appeared on his instrument during the approach. According to the flight recorder trace and cockpit voice recorder the flaps were then lowered in stages to 2°, 5° and 15° at speeds 223, 200 and 166 knots respectively.

"At 0131 hours about 8 miles from touchdown (see Figure 1) the commander informed ATC that the aircraft was established on the ILS localizer. He received clearance to continue the approach and was given the airfield level altimeter setting (QFE). The surveillance radar at Gatwick showed that the aircraft was following the approach centreline exactly. ATC advised the aircraft to climb on the runway heading to 2000 feet (QNH) in the event of a go-around and then cleared it to land, adding that the wind was calm and the RVR was still 100 metres. Approximately 39 seconds later the crew saw from the glide slope pointers on their flight instruments that they were nearing the glide slope. Shortly afterwards, when the airspeed was about 177 knots, the undercarriage was lowered and speed and height slowly decreased. At this point the commander asked the flight engineer to warn him if the 'stabilizer out of trim' warning light illuminated as it had done at Frankfurt. The appropriate reference speeds of 114 knots (minimum approach speed) and 124 knots (go-around speed) were set on the adjustable reference 'bugs' on the port and starboard airspeed indicators respectively. About this time the co-pilot drew the commander's attention to a single red light on the ground, the only one the crew saw during the approach, which the commander recognized as a light at the other end of the runway which was in fact a hazard light on Russ Hill. Some seconds after 0132 hours when the landing gear was locked down the aircraft intercepted the glide slope. The nose went down and the altitude hold switches clicked off. The airspeed according to the flight recorder was 150 knots. From the commander's recollection 25° flaps had been selected by this time but calculations indicate that they were still at 15°. The airspeed then began to build up and shortly after the aircraft had settled on the glide slope the 'stabilizer out of trim' warning light illuminated. The engineer warned the commander, who then saw that the autopilot was trimming the aircraft nose down. Thinking this was wrong, he disconnected the autopilot by means of the control column button switch. This switch automatically sets the flight director to the 'go-around' mode. To continue the approach with the flight director the commander would have had to reselect the 'glide slope manual' mode. This he said he did. At this time, neither pilot noted the pitch indication on the flight director but the commander retrimmed the aircraft slightly nose up, using the control column trim switch. According to the co-pilot's recollection the commander then selected 25° flap but energy calculations based on the flight recorder trace indicated that there had been no change of flap setting at this point.

The aircraft crossed the ILS outer marker on the glide slope at 0133 hours (see Figure 1) and the commander called for 30° flap, which the co-pilot set. Calculations show that the change in the flight path at this point was compatible with a change in flap setting from 15° to 30°. The speed, according to the flight recorder, was 167 knots and the rate of descent about 1000 feet per minute, although the pilots thought that the speed was 140 to 145 knots, and the rate of descent about 600–700 feet per minute. As the flaps extended the rate of descent increased and the aircraft began to go below the glide slope, although it remained accurately on the localizer beam. The pilots remained unaware of the deviation from the glide slope for some time; their recollection was that all the indications continued to appear normal.

The co-pilot had been briefed to call 500 feet on the radio altimeters and 700 feet on the pressure altimeters and this he said he did. The 500 feet call could not be identified on the cockpit voice recorder, but there was a call at 400 feet. The co-pilot thought that at this time the rate of descent was 1000–1200 feet per minute and the speed about 140 knots. These figures agreed reasonably well with those derived from the flight recorder. The commander queried the height of 400 feet and when it was confirmed he tried to trim the aircraft nose up using the trim switch on the control column. There seemed to be no response; the aircraft appeared to pitch nose down and felt nose heavy. Both pilots pulled back on the control column and at the same time the commander applied full power. Both pilots subsequently stated that the control column could only be moved back about an inch.

The aircraft continued to descend and seconds later, as the nose began to rise in response to the application of elevator and power, it brushed through tree tops, knocked a chimney pot off a house and then collided with tree trunks. This impact removed part of the starboard wing and the aircraft began to roll to the right. The aircraft broke clear of the trees and the starboard main wheels touched the ground in a field. The aircraft became airborne again, still rolling to the right, in a nose-high attitude. Then the aft end of the fuselage collided with a house, which it demolished, and the aircraft disintegrated."

Although he was initially established on the ILS glide path, the pilot thus allowed the aircraft to diverge sharply below it from somewhat less than 4 miles off the runway.

It appears from the account reproduced above that several factors may have contributed to this deviation, and it is not for us to attempt to assess which of these factors were the most important. In the present context, the important factor is whether PAR monitoring might have enabled the accident to be avoided, and this was discussed in the accident report.

"Precision Approach Radar (PAR) was permanently withdrawn from operational service at Gatwick Airport on 8 February 1968. Before that date, PAR would monitor aircraft carrying out ILS approaches whenever the cloud was 300 feet or less or the RVR was 1100 metres or less. The RVR at the time of the accident was 100 metres, and if the facility had been in use YA-FAR's approach to runway 27 would have been monitored. The precision radar controller is required to warn the pilot when the aircraft goes outside the safe approach funnel and particularly if it descends below the glide slope. The safe approach funnel is defined as 'a funnel subtending approximately $\frac{1}{2}°$ above and below the glide slope and approximately 2° either side of the final approach track'. If an aircraft remains in the funnel a successful visual landing may reasonably be expected. If an aircraft drifts laterally out of the funnel or its movement from the glide slope centreline indicates that it will shortly go below the funnel, the controller would immediately inform the pilot. If the pilot did not subsequently adjust his rate of descent and the aircraft continued to descend below the glide slope, the precision controller would advise the aircraft to maintain its present height or to climb, according to circumstances.

On the approach that ended in the accident, YA-FAR kept well within the safe approach funnel and on the glide slope until it had descended to a height of about 1000 feet approximately $3\frac{3}{4}$ miles from touchdown. Then the rate of descent increased. If the approach had been PAR monitored the controller would have been alerted at this time to the possibility that the aircraft would shortly go below the funnel and he would have advised the pilot of his deviation from the glide slope and then, if he did not adjust his rate of descent, to maintain height or climb...."

"If PAR had been in use, warning from the controller would have been given to the pilot during the first half of this period, ie about 26 seconds after the start of the high rate of descent mentioned above. Thus the pilot would have received this advice by the time the aircraft reached about 600 feet above the ground, leaving some 25 seconds for recovery to be made before the aircraft reached the ground. In this particular case, therefore, had the approach been monitored by PAR the pilot would have been warned in time to avoid the accident if he took action promptly."*

(*vii*) *Britannia of Britannia Airways near Ljubljana, Yugoslavia, 1 September 1966*[12]

It is not strictly within our terms of reference to discuss the use of PAR monitoring when the approach is not made under ILS guidance but it is relevant to mention the situation where, although ILS is available, it is not used by the pilot who instead concentrates on a visual approach. This may be potentially dangerous because visual contact may be lost during the approach. Such dangers constitute, of course, a case for using ILS during all approaches, but it may be that regulations to this end might be ignored on rare occasions when visibility is good early in the approach.

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[12] Report of the Accident, CAP 303, HMSO, 1968.

* The data quoted in the text of the accident report do not coincide exactly with the diagram reproduced here as Figure 1. The statements in the text are biassed intentionally to the most extreme interpretation of the diagram and lead to the minimum estimate of time remaining for PAR advice to be taken.

An example in which such circumstances may have occurred is the accident to the Britannia at Ljubljana. During an approach at night, the aircraft struck tree tops about 4 miles from and 5 metres below the runway and, as a result, ninety-eight people died and nineteen were injured. The accident report suggests that the probable cause of the accident was errors in altimeter settings resulting in the approach being made some 1250 feet below the procedural safety altitude. It seems that the crew were concentrating on a visual approach (visual contact with the runway lights was reported at 12 miles) but lost visual reference as a result of shallow fog or obstruction by trees. ILS was available, but was probably not used because one receiver was set on the Ljubljana ILS frequency and the other to the Zagreb VOR frequency. Even had PAR been available it might not, of course, have been used in such good weather conditions but, if it had been, such large deviations below the ILS glide path should have been detected.

ILS approaches monitored by PAR

97 Any evidence that PAR monitoring is in some ways ineffective would clearly have an important effect on the decision to withdraw or retain PAR. The reports of accidents which have occurred when PAR has been used to monitor ILS are, therefore, especially important to our inquiry. For this reason the accidents or incidents listed in Table 2 are described briefly below.

(*i*) *Viscount of British United Airways at Frankfurt/Main Airport, 30 October 1961*[13]

The aircraft was on a flight from Berlin and during a missed ILS approach in poor visibility to Frankfurt struck the ground alongside the runway and was badly damaged. Two of the sixteen occupants were injured.

The flight was normal until the final approach when, shortly after passing an altitude of 200 feet, the co-pilot informed the captain that the runway was below them. The captain looked up from his instruments, but could see nothing but a glow; he asked the co-pilot where the lights could be seen and then struck the ground. The touchdown was very hard, in line with the normal point of touchdown, and about 40 metres to the left. After the accident the runway lights could not be seen from the aircraft on the ground, although they were operating at maximum intensity and were only some 50 metres from the aircraft.

During the approach the captain was given advice by the PAR controller. Some 3 minutes before the accident the captain was told that he was left of centreline and later, when the aircraft was about 0·5 nautical miles from touchdown, he was told that he was still 100 feet left, 20 feet above the glide path, and drifting to the left. Shortly before the accident occurred, the PAR controller advised the captain "pull up, go round" but the captain stated that he missed this advice.

The accident report concludes that the cause of the accident was that the captain flew below the critical height when the surface visibility was inadequate, and that a contributing cause was that at the critical moment the co-pilot gave erroneous and misleading information about the visibility of the runway lights.

(*ii*) *Lockheed Constellation of Slick Airways at San Francisco, 3 February 1963*[14]

The aircraft was on a flight from Albuquerque and, on approach to San Francisco, struck approach lights some 1000 feet from the runway threshold. The aircraft crashed and was destroyed and, of the eight occupants, three were killed. During the approach the ILS glide slope receiver was inoperative, and the crew had requested radar advice. The PAR controller gave this until the aircraft had passed the middle marker, and claimed to have continued to monitor the aircraft thereafter and to have observed no deviation from the glide path.

Although the accident report finds that the probable cause of the accident was the continuation of the instrument approach after adequate visual reference was lost below authorized minima, it considered that inadequate monitoring by the PAR controller was a contributory factor. He did not give advice to the crew at all the prescribed distances from the threshold, and did not inform them that he was ceasing to give advice after the middle marker had been passed. Moreover, the report concludes that had the controller, as he stated, continued to monitor the approach after the middle marker he should have observed the dangerous descent below the glide slope and advised the crew.

(*iii*) *Viscount of British United Airways at Gatwick, 8 February 1963*[15]

The aircraft was on a freight flight from Paris and made a PAR-monitored ILS approach to Gatwick. Weather conditions at the time were reported as 8/8 cloud at 200 feet and RVR 1100 yards. The approach was discontinued when the aircraft reached critical height (200 feet) because the pilot was still unable to see the ground. After carrying out an overshoot, the captain decided to hold at Mayfield NDB to await an improvement at Gatwick. After two circuits of the holding pattern had been completed, the captain was informed that the conditions at Gatwick were now 8/8 cloud at 300 feet and RVR 1100 yards, and initiated a second PAR-monitored ILS approach. At ¾ mile from touchdown PAR advised that the aircraft was 200 feet left of centreline and 100 feet above the glide path. At about this time, however, the captain sighted the threshold lights and began an "S" turn to the right to line up with the runway. Shortly afterwards the aircraft touched down just outside the left-hand edge of the runway at a point about 800 yards past the threshold. The nosewheel collapsed on passing through two deep patches of snow.

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[13] *Report on the Inquiry carried out by the Chief Inspector of Accidents, Federal Republic of Germany*, CAP 186, HMSO, 1962.

[14] *Aircraft Accident Report SA-371*, USA Civil Aeronautics Board, 1963.

[15] *A Survey of the Accidents to Aircraft of the United Kingdom* in the year ended 31 December 1963, CAP 211, HMSO, 1964.

(*iv*) *DC-7C of KLM at Geneva/Cointrin Airport, 11 March 1963*[16]

The aircraft was on a flight from Amsterdam and, during an ILS approach, it landed on the last segment of the runway. It over-ran and was seriously damaged. The captain had decided to cut short the normal descent procedure in an attempt to gain time. As a result, although perfect in azimuth, the approach was initiated about 2000 feet too high with the result that the aircraft failed entirely to find the glide path beam despite advice given by PAR monitoring. Having reached the minimum altitude, the pilot ordered re-application of power to execute a missed approach, but shortly afterwards the co-pilot reported that the runway was in sight. The pilot then throttled back, but landed near the end of the runway.

The accident report finds that the accident occurred because the pilot insisted on making the landing without knowing his position relative to the length of the runway in a situation where the instrument approach had been objectively missed.

(*v*) *Vanguard of British European Airways at Heathrow, 27 October 1965*[17]

The aircraft was on a flight from Edinburgh and, after overshooting on a first approach at Heathrow in conditions of poor visibility, the captain initiated a second approach using ILS with PAR monitoring. The PAR controller advised the captain that the aircraft was ¾ mile from touchdown and on the centreline, but 22 seconds later the captain reported that he was overshooting. The PAR controller continued to watch the radar image, saw the aircraft climb to about 400–450 feet and then dive steeply onto the runway. The aircraft in fact hit the runway about 2600 feet from the threshold and was destroyed with all its thirty-six occupants.

The accident report shows that many factors probably contributed to the accident, but that these did not include defects in the approach aids or their use.

(*vi*) *Douglas DC-6B of Belgian International Air Services at Milan-Malpensa, 18 February 1966*[18]

The aircraft was on a cargo flight from Brussels, and made a PAR-monitored ILS approach to Milan in extremely critical visibility conditions because of darkness and fog. The ILS procedure was normal, and the PAR controller started to monitor the flight at 7 miles from touchdown. At 3 miles the aircraft was slightly above and 100 feet to the right of the glide path. At 2 miles it was perfectly aligned, and at 0.5 kilometre it was on the glide slope, but slightly to the left. Thereafter, the aircraft crossed the threshold deviating from the centreline by about 8° to the right; it continued in the general direction of the runway for about 2400 metres, and struck the tops of trees. It subsequently crashed after climbing and stalling and its four occupants were killed.

The accident report concludes that the pilot did not comply with the company visibility minima and that, after his ILS/PAR approach, the pilot probably saw the runway lights suddenly and realized that he was displaced to the left. He turned to the right whilst continuing his descent, and this resulted in a further loss of height. He crossed to the right of the threshold, and probably again lost sight of the lights because of the fog. Time was lost by these manoeuvres in reverting to instrument flight, and the overshoot procedure was delayed. Because of this delay, and because the aircraft was not aligned with the runway, the aircraft struck the trees.

(*vii*) *Caravelle of Thai Airways near Hong Kong, 30 June 1967*[19]

The aircraft was on a flight from Taipei and made an ILS approach monitored by PAR to Hong Kong International Airport at a time when there was heavy rain at the airport. The aircraft remained well within the approach funnel until 3 miles from touchdown, the PAR controller having provided information on weather, overshoot instructions and distance from touchdown.

In his 3 miles distance advisory, the PAR controller informed the pilot that he was a little to the right; this appeared to be corrected, and the aircraft returned to the centreline. At about 2¾ miles the aircraft descended momentarily below the glide slope safety funnel, but returned quickly towards the glide slope before the

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[16] *Aircraft Accident Digest* No. 16, Vol. 1, p. 103, ICAO Circular 82–AN/69, 1968.

[17] Report of the Public Inquiry, CAP 270, HMSO, 1966.

[18] *Aircraft Accident Digest* No. 17, Vol. II, p. 75, ICAO Circular 88–AN/74, 1969.

[19] *Aircraft Accident Digest* No. 17, Vol. II, p. 179, ICAO Circular 88–AN/74, 1969.

PAR controller had made any advisory comment. At 1½ miles the aircraft was again a little right of centreline, and at this time interference from the heavy rain began to obscure PAR reception, firstly in elevation and, shortly after 1 mile, in azimuth also.

About 2 seconds after receiving the 1½ miles PAR advisory, the aircraft was a little right and made a left turn of 14°. Eight seconds later the PAR controller advised that the aircraft was coming back to the centreline and almost immediately it made a right turn through a similar angle. Five seconds later, the PAR controller gave the 1 mile advisory, and the information that the aircraft was going left of centre, after which it increased its rate of turn to the right. On hearing the 1 mile advisory the captain reinforced it by telling the co-pilot, who was flying the aircraft, to move to the right. A moment or two later he saw the sea about 100 feet below and he attempted to pull up, but the aircraft struck the surface and after bouncing settled about 4000 feet before the runway threshold and 100 feet left of the centreline. The aircraft sank rapidly and twenty-four passengers lost their lives.

The accident report notes that the PAR controller should have informed the aircraft when PAR monitoring was interrupted by the heavy rain. It concludes, however, that at the time when the PAR controller could have reported the loss of elevation monitoring, the aircraft was at minimum altitude and also within the safety funnel. At that time such information would have been a neutral fact to the captain, whose attention was concentrated on landing visually or ordering an overshoot; the lack of the PAR report is, therefore, not considered to be a cause of the accident which is attributed to departures from company procedures, inadequate monitoring by the captain, mis-handling of the aircraft by the co-pilot and, possibly, down draughts.

It should be noted that the rainfall at the time was heavy (up to, perhaps, 200 mm/hour) by comparison with conditions encountered near United Kingdom airports.

(viii) *Comet of Sudan Airways at Rome, 29 September 1967*[20]

The aircraft was making a PAR-monitored ILS approach to Rome on a flight from Cairo. Twenty-two seconds prior to impact at a height of about 100 feet it was on the glide path, but it struck the runway very heavily near its right edge some 1000 metres from the threshold. The aircraft received substantial damage but nobody was injured. The accident report makes it clear that the pilot attempted to land under RVR conditions less than the prescribed minima, and that the accident occurred because of an improper landing manoeuvre due to the low visibility. Faults in the approach aids or their use do not appear to have been contributory factors.

98 The only case that we have found of an accident in a PAR-monitored ILS approach in which inadequate PAR monitoring was a contributing factor is, therefore, that to the Slick Airways Constellation on 3 February 1963. It seems clear, however, that the main cause of this accident was the continuation of the approach after visual reference had been lost.

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[20] *Aircraft Accident Digest* No. 17, Vol. II, p. 218, ICAO Circular 88–AN/74, 1969.

CHAPTER 4

Economic considerations

99 The costs of PAR monitoring are as follows:

Telecommunications costs

(i) The cost of maintaining one PAR installation at any airport, including staff, flight checks and GPO lines is £50,000 per annum.

(ii) The cost of maintaining one PAR at Hurn for training only is £16,000 per annum.

(iii) The cost of training telecommunications staff is estimated at £8000 per annum.

Air Traffic Control costs

(i) The staff required to maintain a 24-hour watch at one airport is five ATCO's III at £2525 per head or £12,625 per annum.

In round figures, therefore, the cost per airport is £100,000 per annum which includes no element for the depreciation of capital equipment. With several installations there are slight economies because training costs are partially shared.

100 The cost of an accident involving the loss of an aircraft and its crew and passengers may be roughly £4–£5 millions for a current[21] large jet airliner, and this figure may rise to £50 millions for the largest aircraft expected to be in operation by the mid-1970's. The recurrent costs of PAR monitoring at one airport would thus be offset if one disaster to a current jet airliner could be prevented there every 50 years or, for the largest aircraft considered above, every 500 years. Roughly 130,000 air transport aircraft and 7,000,000 passengers land at Heathrow each year so that the costs of PAR monitoring represent 16*s* 8*d* per air transport aircraft or 3½*d* per passenger landing at the airport.

101 The costs of a diversion due to bad weather conditions are difficult to assess in general terms. For the example of a Trident diverted from Heathrow to Manchester we were told that the costs are approximately £750 which includes both aircraft costs and the costs of meals, accommodation, and alternative transport of passengers and crew. Approximately two hundred diversions occur each year from Heathrow, so that the total saving that might result if these could be avoided is some £150,000 per annum. This is probably a maximum figure because not all diversions would be to places as far away as Manchester and would not usually involve overnight accommodation for passengers.

Although, however, such a figure may be used to support cases for the development of aids to permit landing in worse conditions than current ILS equipment, it is not appropriate to our present inquiry. ILS is basically more accurate than PAR, so that if ILS is available the proportion of diversions that might be avoided by PAR monitoring is small. The costs of an overshoot followed by a successful landing at the same airport are presumably less than those considered above for a diversion, so that it seems unlikely that the contribution of PAR monitoring to the avoidance of overshoots does much to justify its recurrent costs.

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[21] Excluding "jumbo-jets" which have come into service during the course of our inquiry.

CHAPTER 5

Future developments that may affect the position

102 We devoted some time to exploring whether developments that seem likely to occur in the near future would affect the argument concerning the retention or withdrawal of PAR monitoring. In this connection we discussed the development of more advanced (including automatic) landing systems with the Blind Landing Experimental Unit of the Royal Aircraft Establishment and one of us attended the United Kingdom Symposium on Electronics for Civil Aviation held in September 1969. We concluded from these discussions that, because of the time required to introduce new systems, current ILS equipment is likely to remain in use at least on some aircraft or airports for at least 10 years. Moreover, until adequate operational experience has been gained with new equipment we found it difficult to judge whether, when it is introduced, any case for independent monitoring would cease to exist.

103 We also wondered whether new types of aircraft which are much larger than current types, or which approach at larger angles of incidence, would present special problems of PAR monitoring because the position relative to the wheels of the effective radar centre will be different. We corresponded with the manufacturers of the Boeing 747 and the Concorde and came to the conclusion that any problems introduced by such aircraft would not be insoluble with existing PAR equipment.

104 In general, therefore, we concluded that so far as PAR monitoring is concerned the current position is unlikely to change in the near future apart, of course, from changes resulting from increases in the number of aircraft movements which would tend to make the costs of PAR monitoring more justifiable.

CHAPTER 6

Possible alternatives to PAR

105 Some consideration has been given to the provision of an alternative means for monitoring the final approach phase. From the evidence available to us it appears that the most important need is related to those situations where the pilot has not appreciated a positional error correctly presented to him by his instruments. Approach errors arising from unrecognized malfunction of ground or airborne ILS or autopilot cannot, however, be ignored. In the case of recognized ILS failure, diversion to another airport (in the case of an airborne failure to one allowing a visual approach) may provide an adequate safeguard; under dense traffic conditions, however, failures arising, for example, from damage to the localizer aerial, could present serious problems which can only be overcome by an independent approach aid.

106 The failure of the pilot to appreciate the indications of his instruments could be guarded against by an internal cockpit alarm system (eg based on the ILS signals, rate of sink, etc), but it is in just these circumstances that such an alarm seems likely to be ineffective, especially since without further sophistication it will operate while the aircraft is being established on the glide path.

107 For this reason it seems essential for the ground controller to be presented with the position of the aircraft relative to the glide path. The transmission of the ILS error signals by a telemetry link to the ground represents one possible solution, although the complication of additional airborne equipment and the fact that it does not assist in those situations arising from malfunction of the ILS do not recommend it.

108 The combination of plan-position information from existing radar data, and telemetered height, is unlikely to provide sufficiently accurate or sufficiently continuous error monitoring.

109 It therefore appears that monitoring should be based on the provision of an independent high-resolution radar, with a rapid up-dating rate.

110 With the introduction of larger aircraft the position, relative to the wheels, of the effective radar centre (and the movement of this centre with pitch and yaw) may, as discussed above, introduce some difficulties with any radar system. There is as yet inadequate information on the magnitude of these effects but with proper smoothing of the signals it is probable that they will not introduce serious problems. Similar difficulties already exist with respect to the positioning of the ILS aerials and the pilots' view of VASIS.

111 If a successor to PAR were to be developed it is evident that its specification requires further analysis. PAR may be criticized for the following reasons:

(1) The angular accuracy is not really good enough.

(2) The up-date time is too long.

(3) The presentation requires continuous monitoring by a skilled controller and cannot easily be adapted for automatic out-of-glide-path alarm.

(4) In the final stages of the approach and under conditions of heavy rain, its performance is limited by clutter.

112 As the work of DORA (see Chapter 3) has shown, a relatively cheap lock-follow system can provide an accuracy perhaps ten times better than PAR in each coordinate; furthermore, the information is virtually continuous and so the derivation of the rate of change of error is straightforward. It would therefore be relatively simple to construct a system capable of providing *automatic* warning to the controller of a potentially serious deviation from the glide path.

113 A simple mechanical lock-follow system of this kind is not, however, suitable for monitoring the approach of more than one aircraft at a time. If monitoring must begin as soon as aircraft are established on the glide path, there might, under conditions of maximum density, be three to four aircraft to be monitored simultaneously.[22]

114 In order to overcome this limitation a system employing electronic scanning might be employed to provide simultaneous tracking of a number of aircraft

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[22] PAR does not in fact achieve this because of the need to change the range-scale and sector-scan in the final stages, but any new system might be required to do so.

and provide for each an automatic warning of glide path deviation. It could also display the data to the controller (in a more precise and convenient manner than in PAR) so that if required a full talk-down facility is available. Any new system of this kind could be equipped with effective means for eliminating ground and rain clutter.

115 The ability to provide an automatic alarm not only makes it feasible to monitor every approach, but could also provide automatically a permanent record of those approaches which exceed some specified departure from the glide path. The subsequent analysis of these records might make a substantial long-term contribution to safety.

CHAPTER 7

Summary and discussion of the evidence

116 ILS is the internationally-accepted approach aid and the most accurate aid in routine use; at Heathrow alone over eleven thousand landings (some 9 per cent of total landings) during 1969 required ILS. We have been impressed in the evidence that we have seen by the accuracy and reliability of the large majority of the approaches made with ILS. With few exceptions, the organizations and individuals consulted by us express high opinions of its general performance, and many refer to the further developments of the system that seem possible and that should be encouraged.

117 No system can, however, be completely reliable and, because the potential consequences of an approach error in bad weather are so serious, it is inevitable that a central theme of our inquiry should be a study of the occasions on which the system has proved unsatisfactory. Such a study involves, of course, not only the performance of the ILS equipment but, because the information provided by ILS is available only in the aircraft, the use made of it by pilots.

118 So far as the reliability and accuracy of ILS equipment is concerned, two cases should perhaps be considered separately. Firstly, there is the situation where, before an approach is initiated, it is known that the ground or airborne ILS equipment is faulty. Economic problems might result from this situation because a runway might have to be closed in conditions of poor visibility, or aircraft might need to be diverted. Several organizations and individuals have commented on the role that PAR can play as an alternative to ILS in such situations in order to enable a runway to remain open when the ILS is out of service because of maintenance or modifications. Manchester airport, for example, express the view that it is essential to retain their PAR for this reason because modifications are expected to interrupt the availability of ILS for the coming 2 or 3 years.

119 Although affecting the regularity of operations, the situations described above should not be potentially dangerous if they are recognized and acted upon, even if PAR is not available as an alternative aid. Diversions should be possible to an airport where visual landing is possible or (if the diversion results because the ILS ground equipment is out of service) where ILS can be used.

120 Failures or errors of ILS that are not fully apparent before an approach is initiated, or that occur during an approach, represent more serious safety problems. There is general agreement in the evidence that modern ILS equipment is highly reliable, although one organization mentions that some older equipment still installed in some aircraft is less satisfactory in this respect. The Guild of Air Traffic Control Officers also mentions that Category II ILS is more subject to "tripping" than Category I; in some circumstances the integrity of the ILS data received by the aircraft may be seriously affected by reflections or other interfering signals. Other organizations also refer to occasional errors or failures of ILS and there is evidence from PAR logs, pilots' reports, and the report of the Schiphol experiments that failures sometimes occur. Nevertheless, we have seen very little clear evidence of accidents that have occurred because faults in the ground or airborne ILS equipment have been undetected or have occurred suddenly during an approach.

121 It appears from the DORA and Schiphol evidence and from PAR logs that in a small proportion of landings there are considerable deviations from the ILS glide path, although it is not clear whether these deviations arise from ILS instrumentation or from other causes such as the pilot's use of ILS. There is no clear evidence that such deviations are potentially dangerous, indeed the DORA evidence shows that safe landings are made even when large deviations have been present before the landing became visual. Nevertheless, it is clear that the high standards of accuracy achieved in most ILS landings are not always realized and, if further investigation showed that the pilots were sometimes unaware of the deviations or were unable to control them on the basis of ILS instrumentation, potential dangers would exist.

122 Partly because substantial deviations from the glide path or malfunction of equipment in ILS approaches are rare, and partly because they are not fully documented, we have not found it possible to conduct a statistical analysis which might indicate the probability of occurrence or the potential dangers that might result.

123 The occurrence of accidents or incidents during or after ILS approach is fortunately rare. There are,

however, several examples (some of which are described in our report) which show that large deviations from the glide path have sometimes occurred with dangerous or disastrous results. In most of these examples the fault appears to be associated with the use of ILS by the aircrew rather than with faults in the equipment. Inadequate use of the ILS system is, of course, often only one factor contributing to these accidents or incidents and it is sometimes difficult to judge whether it is the major factor. In some cases the departure from the glide path appears to have occurred when the pilot is effectively ignoring the ILS display and concentrating on a visual approach; errors in setting the altimeter have sometimes contributed to these departures.

124 We conclude, therefore, that for reasons that are sometimes complex and often not clear ILS is occasionally ineffective and deviations occur from the glide path. Moreover, we suspect that, because information on these events is widely scattered or not recorded, they occur more frequently than the examples that we have been able to identify. Because their causes are often at least partially unknown, it is difficult to assess how helpful PAR monitoring was or might have been in these examples. There is evidence in the recent PAR logs and pilots' comments that PAR monitoring has been helpful on several occasions, and there are a few instances in which guidance during an ILS approach was taken over fully by PAR. It is not, however, known whether in any of these cases the absence of PAR monitoring would have created potentially dangerous circumstances; indeed the pilots' comments sometimes show that, even when PAR monitoring proved very helpful, there was little probability of danger had it not been available. Although, however, we place great weight on pilots' opinions in such circumstances we have their comments in only a few cases where PAR intervention took place. There must also be real difficulties in forecasting the development of the hypothetical situation in which PAR monitoring was not available, although it seems clear that a few of the accidents that we have discussed might have been avoided had PAR monitoring been used.

125 There is evidence from the PAR logs that PAR monitoring has probably avoided the need for overshoots in a number of recent ILS landings, and has thus contributed to the economy and regularity of services.

126 Because the number of well-documented examples of the contributions of PAR monitoring is small, general considerations and the views expressed by organizations and individuals must play an especially important part in our inquiry. We have commented above on the view expressed to us on several occasions that PAR is a valuable alternative when ILS is not available because of maintenance or modifications. Apart from this point, and the case (excluded from our terms of reference) where parallel runways are in simultaneous use, the strongest general arguments in favour of PAR monitoring come from pilots.

127 BALPA argue that an independent navigational facility is required as a basic principle, and that "PAR is always valuable in providing a cross-check which is entirely independent, during the late stages of an approach". The Association points out that a high proportion of accidents occurs during the approach phase and also that, if the monitoring function is taken into account, the utilization of PAR is not low. It is argued that the use of PAR should be retained, and equipment and operating practice improved, and the Association concludes: "the decision to withdraw PAR from United Kingdom airfields was unwise and should be reversed. The Association further considers that pressure should be brought to bear internationally to emphasize the need for PAR as an independent cross-check facility and a standby facility for use in the event of ILS failures".

128 IFALPA considers that PAR monitoring is essential at high-density traffic aerodromes and where, as discussed below, the ILS beam is known to suffer from instability due to terrain effects.

129 The BALPA opinion has been criticized because it is not based on clearly reasoned arguments, and because it places emphasis on the need for PAR monitoring during the late stages of an approach where the ability of the PAR controller to intervene in time to prevent an accident is most doubtful. We accept the first of these criticisms but, having ourselves experienced the difficulty of identifying well-documented examples, we sympathize with the problems of formulating reasoned arguments. We feel that in the present state of knowledge the decision on the future of PAR monitoring must be based to some extent on opinion rather than fact, and that so far as operational performance is concerned pilots and PAR operators are probably in the best position to express these opinions. The second criticism concerning the use of PAR monitoring in the late stages of an approach depends, of course, on the definition of the word "late". Because of the delay in passing information to the pilot PAR monitoring would clearly be ineffective very close to the runway. On the other hand, there is clear evidence that gross departures from the ILS glide path sometimes begin at considerable distances from the runway, and it is such gross departures that are, of course, most dangerous. In the Ariana disaster at Gatwick PAR intervention would have taken place some 3 miles from touchdown and would have been early enough for the accident to have been avoided if the pilot responded promptly. We also note that the BALPA opinion is not based entirely on the value of monitoring during the late stages of approaches.

130 The pilot's associations are, of course, concerned mainly with the potential contributions of PAR monitoring to safety, and a more powerful criticism might be based on the grounds that they are less concerned with the costs of monitoring so that cost-effectiveness considerations are given little weight. BALPA comments, however, on the utilization of PAR monitoring, and it is probable that IFALPA have economic factors partly in mind when they distinguish between low- and high-traffic density airports.

131 In addition to these general opinions, the following specific arguments have been advanced in favour of PAR monitoring:

(i) That it is required for airports where local conditions lead to abnormally frequent occurrences of the unreliability of ILS. IFALPA express the view that monitoring is essential where the ILS beam is known to suffer from instability and quote terrain effects at Genoa as an example. ICAO argue that the decision regarding retention or withdrawal of PAR facilities must be based primarily on local factors. The Guild of Air Traffic Control Officers refers to the possibility of spurious ILS guidance signals resulting from reflections and other radiations.

So far as we know, no major United Kingdom airport is especially subject to such local effects, although we were told that at Manchester 24 ILS localizer tends to bend north in certain weather conditions.

(ii) That it reduces the strain on pilots. The reduction of strain or the feeling of comfort amongst pilots that results from the knowledge that an ILS approach is independently monitored is mentioned by several individuals and authorities. If, as a result, the pilot is able to perform his duties (including duties other than those associated with the use of ILS) more efficiently during the approach and landing, a contribution to safety would result. It would be extremely difficult to evaluate this contribution, and we note that it is not mentioned explicitly by either BALPA or IFALPA. Nevertheless, we feel that strain must be to some extent alleviated by the knowledge that there is independent monitoring, especially if the approach is being made in marginal weather conditions or at the end of a long period of duty, If the pilot has reason to suspect the reliability of his ILS equipment, or in an emergency situation, we imagine that the effect would be greater. We have, however, no clear evidence that alleviation of strain by PAR monitoring has of itself led to the avoidance of a potentially dangerous situation.

(iii) PAR monitoring enables the horizontal separation of aircraft making ILS landings to be monitored and controlled. Other ATC practices should enable such dangers to be avoided, but we were told that the presence of several aircraft with widely different performance capabilities on the approach sometimes presents a worrying situation. PAR monitoring could make a contribution here, but we have no evidence of potential dangers with existing procedures.

(iv) PAR monitoring enables local flying aircraft to be detected so that they may be controlled and appropriate warnings given. This case differs from that referred to above because it includes aircraft not making an approach. Again, PAR monitoring could make some contribution but, as in the previous paragraph, we would regard this as a side benefit and not by itself an argument for retaining PAR monitoring because other ATC procedures should control local flying aircraft. Moreover, the angle covered by the PAR beam limits its value in this application.

132 Other arguments in favour of PAR monitoring are that it can be used as an approach aid for aircraft not equipped with ILS, and that it is valuable to airport authorities for noise monitoring. Both of these arguments lie outside our terms of reference although, if it was decided to retain PAR for other reasons, they might in some situations improve its cost effectiveness.

133 The argument against the retention of PAR monitoring is based mainly on economic and manpower considerations. The recurrent costs of an installation including maintenance, training and staff costs is approximately £100,000 and five ATC operators are needed for the installation. Such costs would be offset if one accident involving the destruction of a typical current large jet aircraft and its passengers could be prevented in 50 years or if the destruction of one of the largest aircraft expected to be in operation by the mid-1970's could be avoided in 500 years. The costs represent less than £1 per aircraft landing at Heathrow or less than 3½*d* per passenger. We appreciate, however, that such arguments may be used equally to justify expenditure on other aids to flight safety, and that relative priorities must be considered in order to determine how the available funds can best be used, or to formulate a case for the provision of additional funds. To attempt this would be beyond our terms of reference, but we note the recommendation of ICAO that: "ILS remains the primary landing aid at international aerodromes and it would therefore appear that in all those cases where the decision to maintain or install a PAR is likely to adversely affect the presence of the ILS, be it due to dispersal of funds or manpower, priority should definitely be given to ensuring the highest possible standard of operation of the ILS concerned". We recall also that Mr Johnson

of the FAA told us that the decision to withdraw PAR in the USA was influenced to some extent by considerations of the large number of USA airports having no approach aids.

134 The economic effects of PAR in preventing diversions and overshoots are, probably, small compared with the costs of providing PAR monitoring.

135 Other evidence against the retention of PAR monitoring comes from the experience at airports where it has been withdrawn without adverse effects. Thus, we note the statement from the Netherlands: "Our experience since the withdrawal of the PAR at Schiphol Airport" is that "no need is felt to maintain the facility neither by the pilots who call at Schiphol regularly, nor from the point of view of improvement of the operational performance of the service". Such experience is powerful evidence, but it may be argued that accidents occur rarely, and that information is required over a longer period before it can form the basis of firm conclusions. In contrast to the Netherlands experience, it should be recalled that the disaster to the Boeing 727 at Gatwick occurred within less than 1 year after withdrawal of PAR.

136 Another argument is based on the finding that PAR monitoring seldom makes a useful contribution or is seldom used, and this appears to have been the major argument leading to the withdrawal of PAR in the USA. Because of differences in the USA practice of using PAR, and especially the use of a separate communications channel, we doubt whether their findings are representative of the situation in the United Kingdom. There is evidence from PAR logs at Heathrow and Manchester that interventions that are at least helpful occur quite frequently.

137 A technical argument against PAR is that because of the delay that results between the occurrence of a deviation from the ILS glide path and the pilot being informed, the system becomes ineffective close to the runway. This certainly limits the value of PAR monitoring, but we note that there is evidence from the accident reports and PAR logs of deviations from the ILS glide path at considerable distances from touchdown which were, or might have been, dangerous if not corrected. It has also been suggested that the incidence of overshoots is greater when aircraft are not established accurately on the ILS glide path at an early stage of the approach.

138 We have seen no evidence that PAR monitoring may make an adverse contribution to safety. The only comment in this direction is that it might distract the aircrew from performing other duties during the approach. The evidence of accidents that have occurred during ILS approaches with PAR monitoring reveals no fundamental weakness of PAR monitoring, and is thus of a negative character which does not affect our inquiry.

139 Looking to the future it seems likely that developments in approach guidance will eventually permit landings to be made under automatic guidance in weather conditions worse than those now acceptable for ILS approaches. In such circumstances the value of PAR monitoring in the final stage of an approach would be even less than at present, because approaches will be continued close to the runway even under conditions of very low visibility. The need for monitoring in the earlier stages of an approach would depend on the reliability of the primary approach aid, and we are unable to predict this. It seems likely, however, that technical developments and refinements in operating procedures would eventually make the reliability of new systems even greater than for ILS systems in current use. It seems, therefore, that the need for PAR monitoring may become weaker in the future, but we were told that a period of 10 years may elapse before new systems permitting automatic landing in Category III conditions are in routine operational use.

140 We have explored whether the radar images of new aircraft now coming into service (especially very large aircraft or aircraft with large angles of incidence during the approach) would be such that PAR monitoring would be difficult, especially if conventional aircraft have to be monitored with the same installation. It seems unlikely that major problems would arise.

141 Although not strictly within our terms of reference, we have also given some thought to the possibility of using systems other than the current types of PAR for monitoring with the object of improving accuracy and reducing running costs and manpower requirements.

CHAPTER 8

Conclusions

142 No system can be completely reliable and our inquiry shows that deviations from the ILS glide path sometimes occur. The evidence is scattered and incomplete, and we are sure that we have not identified all such cases; the number is certainly small compared with the total number of ILS landings but large enough to be, in our view, a source of concern at least until the reasons for their occurrence and the extent to which they are potentially dangerous are better understood. In the examples that we have examined the reasons are usually unknown and, in particular, it is often uncertain whether they are associated with the ILS equipment, the handling characteristics of the aircraft, or the way in which the ILS is used by the pilot. With the exception of a few accident reports, there is no firm evidence that such deviations lead to dangerous situations; indeed it seems from the DORA studies that satisfactory landings are usually made even when large deviations have occurred, perhaps because corrections can be applied after the approach becomes visual.

143 Nevertheless there can presumably be no doubt that an approach in which there are substantial deviations from the ILS glide path, even at a distance from the runway where PAR intervention might be effective, is likely to be less safe than an approach which follows the ILS glide path accurately. When gross departures from the ILS glide path occur, as in the Ariana disaster, the dangers are obvious. For these reasons there can be little doubt that PAR monitoring can contribute to safety, and this view is shared on these or other grounds by the majority of individuals and organizations that we have consulted.

144 This conclusion could probably have been anticipated before our inquiry began, because it would be surprising on general considerations if independent monitoring of any system (especially if it includes a human element) did not contribute to its reliability. If safety is to be sought at any price the position would be clear, but this is, of course, not the position. To assess whether the costs and manpower required for PAR monitoring are justifiable, it is necessary to explore its contribution to safety in quantitative terms. We have found this extremely difficult, because inadequate information is available on the magnitudes of departures from the ILS glide path that are potentially dangerous, and the frequency of and reasons for their occurrence. Work is in progress at DORA on these topics, and we have already expressed our support for their attempts to secure from pilots explanations for deviations when they are observed. Evidence from PAR monitoring is also valuable, and we have again supported attempts to secure pilot comments when interventions prove necessary.

145 Until these programmes have produced more data and these have been studied, it will be difficult to assess in quantitative terms the contribution made by PAR monitoring. On the basis of the information now at our disposal, we feel that in its present stage of usage significant deviations from the ILS glide path occur sufficiently often to be a source of concern, at least until the reasons are better understood. In particular, we cannot be certain that gross deviations such as in the Ariana disaster will never recur.

146 It is possible that improvements in flight-deck management procedures or ILS systems and their methods of use will reduce these problems, and we support any action that may be taken in this direction. We are, however, uncertain of how quickly and completely such measures could be effective. Recognizing that we should err on the side of safety, we feel that at least for the next few years and at busy airports PAR monitoring is likely to make a contribution to safety that justifies its costs and manpower requirements.

147 It is, of course, not for us to determine what action should be taken on the basis of this conclusion, especially because we are not concerned with other facilities contributing to safety that may compete with PAR for the available funds and manpower. If the potential contribution of any other facility is judged to exceed that of PAR we would, of course, give it priority. We also support the view expressed by ICAO that PAR monitoring should not slow down the extending or refinement of ILS facilities. We hope, however, that sufficient funds will be provided to provide PAR monitoring without slowing the development and installation of other facilities which contribute to safety or the regularity of service; the unit costs of PAR per passenger or aircraft are low.

148 Although we sympathize with the opinion expressed by one airport authority that if PAR monitoring is retained at some it should be extended to all

airports, we must regard this as unrealistic on grounds of cost effectiveness. Traffic density should be taken into consideration in determining the airports to be equipped, as argued by IFALPA and others. The type of operation is also a relevant factor, and special consideration should be given to airports at which a high proportion of landings is made by pilots who may be accustomed to flying in areas where the weather conditions require ILS to be used only rarely.

149 We suggest that, if it is accepted that PAR monitoring can make a useful contribution at the present, it should be retained or installed only at airports selected on such grounds, or which may be essential for diversions. We understand that equipment exists which should enable this to be done at any airport controlled by the Board of Trade that might be considered appropriate (eg Gatwick).

150 If this is done all PAR installations should be used not only for monitoring, but to augment the data now being obtained by DORA at Heathrow on the accuracy of ILS approaches. A final decision on the future of ILS monitoring and in particular on the ordering of new equipment cannot be made until the reasons for the occasional deviations from the ILS glide path are understood. At the same time it is important that preliminary consideration now be given to the technical specification of a replacement for PAR. It is possible that a system having both greater accuracy and freedom from ground and rain clutter could be provided economically, but an investigation should be made into the way in which such equipment would be integrated into the general ATC system, including the acquisition of aircraft, and the display.

151 Although our main consideration must centre round the reliability of landings under ILS, numerous other contributions of PAR have been brought to our attention. Although on the evidence that we have seen none of these would individually justify PAR monitoring on the grounds of safety alone, they may contribute to justifying the costs of PAR on other grounds.

152 Subject to these general comments, our main conclusions are summarized below:

(i) A majority of the organizations and individuals that we have consulted agree that PAR monitoring of ILS landings contributes to safety, although the strength of opinion varies greatly.

(ii) Opinion on whether the contribution to safety justifies the retention or extension of PAR monitoring is divided. At one extreme pilots' associations regard it as essential at least at airports where the traffic density is high. At the other extreme IATA fears that its retention would delay the extension and development of ILS, and the Board of Trade feels that its potential contribution is small and that efforts should be concentrated on perfecting the use of ILS.

(iii) Views in foreign countries are also divided, but we have reservations about the relevance of basis for some decisions to the position in the United Kingdom.

(iv) We regard experience in the Netherlands, where the withdrawal of PAR monitoring has led to no difficulties, as particularly relevant. It could be argued, however, that this experience has been over too short a period to be conclusive.

(v) There is evidence from work at DORA on the monitoring of ILS approaches, from PAR logs, and from accident reports that substantial deviations from the ILS glide path sometimes occur.

(vi) Most ILS approaches are, of course, not monitored and we suspect that such deviations occur more frequently than the examples that we have been able to identify.

(vii) The reasons for these deviations are usually not known.

(viii) Safe landings are usually made even when the deviations from the ILS glide path are large, presumably because corrections are applied once the approach becomes visual.

(ix) Nevertheless, an approach in which such deviations occur seems likely to be less safe than when they are absent.

(x) The time that necessarily elapses between the detection by the PAR controller of a substantial deviation from the glide path and action being taken by the pilot in response to advice from the PAR controller makes monitoring ineffective close to touchdown.

(xi) Nevertheless, there have been cases where large deviations have occurred at sufficient distance from touchdown for PAR to be effective. The Ariana disaster at Gatwick, and probably some other accidents, could have been avoided if PAR monitoring had been used, and the pilot had been able to act promptly on advice from the PAR controller.

(xii) The available evidence does not permit the contribution of PAR monitoring to be assessed in quantitative terms, or for a reliable study to be made of its cost effectiveness. The recurrent costs of a PAR installation would, however, be offset if it could prevent a disaster to one large current jet aircraft in 50 years. This may rise to as much as 500 years for the largest aircraft expected to be in operation by the mid-1970's. At Heathrow the recurrent costs of PAR monitoring represent at present less than £1 per aircraft landing and approximately 3½*d* per passenger landing. Unit costs would, of course, be higher at airports where the traffic density is lower but, as argued above, the type of operation as well as the traffic density may be an important factor in determining the airports at which PAR monitoring is most justified. We recognize that in such cases the taxpayer or (through user charges) the airlines with regular experience of ILS approaches may, in effect, be required to subsidize certain less experienced airlines, but (unless some scheme of differential charges could be devised) we regard this as inescapable in the interests of overall safety.

(xiii) It might be argued that the type of operation rather than the total traffic density should be the basis for determining whether PAR monitoring is justified at a particular airport. Until further evidence is available we would not support such an argument; the DORA studies and PAR logs for Heathrow (where the majority of pilots is, presumably, very familiar with the conditions prevailing in northern Europe) suggest that significant deviations from the ILS glide path sometimes occur. On the existing evidence, we feel that considerations of the type of operation may justify PAR monitoring even at airports where the traffic density is relatively low, but do not obviate the case for monitoring at high traffic density airports even if used mainly by experienced operators.

(xiv) Accidents have occurred when PAR monitoring has been used but it is clear that in most cases inadequate PAR monitoring has not contributed to these accidents.

(xv) Having considered the evidence at our disposal, we conclude that PAR monitoring of ILS approaches makes a useful general contribution to safety, and that situations sometimes occur in which this contribution could be decisive.

CHAPTER 9

Recommendations for future action

153 The principal recommendations arising from our inquiry are:

(i) The existing PAR installations at Heathrow and Manchester should be retained and manned for the present.

(ii) Taking into account traffic density, the type of operation, local topographical and meteorological conditions, and the relative priorities of other aids to safety (see below), consideration should be given to the introduction of routine PAR monitoring at other United Kingdom airports (eg Gatwick).

(iii) Detailed logs should continue to be kept by PAR operators, especially of interventions involving large departures from the ILS glide path.

(iv) Every support should be given to the monitoring of ILS landings by DORA at Heathrow, and to their attempts to define deviations from the glide path that are potentially dangerous. It might also be worthwhile to explore whether additional information on the accuracy of ILS approaches can be obtained by examining the records of flight data recorders. They may supplement the data from DORA observations and PAR monitoring and provide information for aerodromes at which such independent observations on the accuracy of ILS approaches are not made.

(v) Existing attempts to seek from pilots explanations for deviations from the ILS glide path observed by PAR operators or DORA monitoring should be intensified. Both BALPA and IFALPA favour[23] PAR monitoring, and should be approached for their support.

(vi) DORA should be invited to collate the information received under recommendations (iii), (iv) and (v) so that a clear picture is built up of the uses of PAR monitoring and the accuracy and reliability of approaches using ILS guidance.

(vii) The position should be reviewed when information is forthcoming as a result of these recommendations. We feel that this may require between 1 and 2 years.

(viii) Apart from any operational inadequacies, the life of the existing PAR equipment is presumably limited for engineering reasons. It follows that if it is accepted that monitoring may make a continuing contribution to safety, consideration should be given at an early date to the provision of a replacement for PAR. As a first step, the operational requirements of a monitoring system would need to be defined so that a technical specification could be prepared.

154 Our terms of reference have not included other facilities that might contribute to safety, and the above recommendations are made on the assumption that they will not delay the development or installation of any facility judged to have a greater potential contribution to safety. If it is not clear that this will be so, we recommend that a study be made to assess priorities.

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[23] In the case of IFALPA at high traffic density airports like Heathrow.

APPENDIX 1

Precision approach radar

Extracts from Annex 10 to the Convention on International Civil Aviation

3.2.3 The Precision Approach Radar Element (PAR)

3.2.3.1 *Coverage*

3.2.3.1.1 The PAR shall be capable of detecting and indicating the position of an aircraft of 15 square metres (165 square feet) echoing area or larger, which is within a space bounded by a 20° azimuth sector and a 7° elevation sector, to a distance of at least 9 nautical miles from its respective antenna.

3.2.3.2 *Siting*

3.2.3.2.1 The PAR shall be sited and adjusted so that it gives complete coverage of a sector with its apex at a point 150 metres (500 feet) from the touchdown in the direction of the stop end of the runway and extending plus or minus 5° about the runway centreline in azimuth and from minus 1° to plus 6° in elevation.

3.2.3.3 *Accuracy*

3.2.3.3.1 *Azimuth accuracy.* Azimuth information shall be displayed in such a manner that left–right deviation from the on-course line shall be easily observable. The maximum permissible error with respect to the deviation from the on-course line shall be either 0·6 per cent of the distance from the PAR antenna plus 10 per cent of the deviation from the on-course line or 9 metres (30 feet), whichever is greater. The equipment shall be so sited that the error at the touchdown shall not exceed 9 metres (30 feet). The equipment shall be so aligned and adjusted that the displayed error at the touchdown shall be a minimum and shall not exceed 0·3 per cent of the distance from the PAR antenna or 4·5 metres (15 feet), whichever is greater. It shall be possible to resolve the positions of two aircraft which are at 1·2° in azimuth of one another.

3.2.3.3.2 *Elevation accuracy.* Elevation information shall be displayed in such a manner that up–down deviation from the descent path for which the equipment is set shall be easily observable. The maximum permissible error with respect to the deviation from the on-course line shall be 0·4 per cent of the distance from the PAR antenna plus 10 per cent of the actual linear displacement from the chosen descent path or 6 metres (20 feet), whichever is greater. The equipment shall be so sited that the error at the touchdown shall not exceed 6 metres (20 feet). The equipment shall be so aligned and adjusted that the displayed error at the touchdown shall be a minimum and shall not exceed 0·2 per cent of the distance from the PAR antenna or 3 metres (10 feet), whichever is greater. It shall be possible to resolve the positions of two aircraft that are at 0·6° in elevation of one another.

3.2.3.3.3 *Distance accuracy.* The error in indication of the distance from the touchdown shall not exceed 30 metres (100 feet) plus 3 per cent of the distance from the touchdown. It shall be possible to resolve the positions of two aircraft which are at 120 metres (400 feet) of one another on the same azimuth.

3.2.3.4 Information shall be made available to permit the position of the controlled aircraft to be established with respect to other aircraft and obstructions. Indications shall also permit appreciation of ground speed and rate of departure from or approach to the desired flight path.

3.2.3.5 Information shall be completely renewed at least once every second.

APPENDIX 2

Instrument landing system

Extracts from Annex 10 to the Convention on International Civil Aviation

3.1.2 Basic requirements

3.1.2.1 The ILS shall comprise the following basic components:

(a) VHF localizer equipment, associated monitor system, remote control and indicator equipment;

(b) UHF glide path equipment, associated monitor system, remote control and indicator equipment;

(c) VHF marker beacons, associated monitor systems, remote control and indicator equipment.

3.1.2.2 The ILS shall be constructed and adjusted so that, at a specified distance from the threshold, similar instrumental indications in the aircraft represent similar displacements from the course line or ILS glide path as appropriate, irrespective of the particular ground installation in use.

3.1.2.6 To ensure an adequate level of safety, the ILS shall be so designed and maintained that the probability of operation within the performance requirements specified is of a high value, consistent with the category of operational performance concerned.

3.1.2.7 At those locations where two separate ILS facilities serve opposite ends of a single runway, an interlock shall ensure that only the localizer serving the approach direction in use shall radiate, except where the localizer in operational use is Facility Performance Category I — ILS and no operationally harmful interference results.

3.1.2.7.1 At locations where, in order to alleviate frequency congestion, the ILS facilities serving opposite ends of one runway employ identical paired frequencies, an interlock shall ensure that the facility not in operational use cannot radiate.

3.1.3 VHF localizer and associated monitor

3.1.3.1 *General*

3.1.3.1.1 The radiation from the localizer antenna system shall produce a composite field pattern which is amplitude modulated by a 90 c/s and a 150 c/s tone. The radiation field pattern shall produce a course sector with one tone predominating on one side of the course and with the other tone predominating on the opposite side.

3.1.3.1.2 When an observer faces the localizer from the approach end of runway, the depth of modulation of the radio frequency carrier due to the 150 c/s tone shall predominate on his right hand and that due to the 90 c/s tone shall predominate on his left hand.

3.1.3.3 *Coverage*

3.1.3.3.1 The localizer shall provide signals sufficient to allow satisfactory operation of a typical aircraft installation within the localizer and glide path coverage sectors. The localizer coverage sector shall extend from the centre of the localizer antenna system to distances of:

> 25 nautical miles within plus or minus 10° from the front course line;
>
> 17 nautical miles between 10° and 35° from the front course line;
>
> 10 nautical miles outside of plus or minus 35° if coverage is provided;

except that, where topographical features dictate or operational requirements permit, the limits may be reduced to 18 nautical miles within the plus or minus 10° sector and 10 nautical miles within the remainder of the coverage when alternative navigational facilities provide satisfactory coverage within the intermediate approach area. The localizer signals shall be receivable at the distances specified at and above a height of 600 metres (2000 feet) above the elevation of the threshold, or 300 metres (1000 feet) above the elevation of the highest point within the intermediate and final approach areas, whichever is the higher. Such signals shall be receivable, to the distances specified, up to a surface extending outward from the localizer antenna and inclined at 7° above the horizontal.

3.1.3.7 *Identification*

3.1.3.7.1 The localizer shall provide for the simultaneous transmission of an identification signal, specific to the runway and approach direction, on the same radio frequency carrier or carriers as used for the localizer function. The transmission of the identification signal shall not interfere in any way with the basic localizer function.

3.1.3.7.3 The identification signal shall employ the International Morse Code and consist of two or three letters. It may be preceded by the International Morse Code signal of the letter "I", followed by a short pause where it is necessary to distinguish the ILS facility from other navigational facilities in the immediate area.

3.1.3.8 *Siting*

3.1.3.8.1 The localizer antenna system shall be located on the extension of the centreline of the runway at the stop end, and the equipment shall be adjusted so that the course lines will be in a vertical plane containing the centreline of the runway served. The antenna system shall have the minimum height necessary to satisfy the coverage requirements laid down in 3.1.3.3, and the distance from the stop end of the runway shall be consistent with safe obstruction clearance practices.

3.1.3.9 *Monitoring*

3.1.3.9.1 The automatic monitor system shall provide a warning to the designated control points and cause one of the following to occur, within the period specified in 3.1.3.9.3.1, if any of the conditions stated in 3.1.3.9.2 persists:

(a) radiation to cease;

(b) removal of the navigation and identification components from the carrier;

(c) reversion to a lower category in the case of Facility Performance Categories II and III localizers where the reversion requirement exists.

3.1.3.9.2 The conditions requiring initiation of monitor action shall be the following:

(a) for Facility Performance Category I localizers, a shift of the mean course line from the runway centreline equivalent to more than 10·5 metres (35 feet) at the ILS reference datum;

(b) for Facility Performance Category II localizers, a shift of the mean course line from the runway centreline equivalent to more than 7·5 metres (25 feet) at the ILS reference datum;

(c) for Facility Performance Category III localizers, a shift of the mean course line from the runway centreline equivalent to more than 6 metres (20 feet) at the ILS reference datum;

(d) in the case of localizers in which the basic functions are provided by the use of a single-frequency system, a reduction of power output to less than 50 per cent of normal, provided the localizer continues to meet the requirements of 3.1.3.3, 3.1.3.4 and 3.1.3.5;

(e) in the case of localizers in which the basic functions are provided by the use of a two-frequency system, a reduction of power output for either carrier to less than 80 per cent of normal, except that a greater reduction to between 80 per cent and 50 per cent of normal may be permitted, provided the localizer continues to meet the requirements of 3.1.3.3, 3.1.3.4 and 3.1.3.5;

(f) change of displacement sensitivity to a value differing by more than 17 per cent from the nominal value for the localizer facility.

3.1.3.9.3 The total period of radiation outside the performance limits specified in (a), (b), (c), (d), (e) and (f) of 3.1.3.9.2 shall be as short as practicable, consistent with the need for avoiding interruptions of the navigation service provided by the localizer.

3.1.3.9.3.1 The total period referred to under 3.1.3.9.3 shall not exceed under any circumstances:

10 seconds for Category I localizers;

5 seconds for Category II localizers;

2 seconds for Category III localizers.

3.1.4 UHF glide path equipment and associated monitor

Note θ is used in this paragraph to denote the nominal glide path angle.

3.1.4.1 *General*

3.1.4.1.1 The radiation from the UHF glide path antenna system shall produce a composite field pattern which is amplitude modulated by a 90 c/s and a 150 c/s tone. The pattern shall be arranged to provide a straight line descent path in the vertical plane containing the centreline of the runway, with the 150 c/s tone predominating below the path and the 90 c/s tone predominating above the path to at least an angle equal to 1·75 θ.

3.1.4.1.2.2 The glide path angle shall be adjusted and maintained within:

(a) 0·075 θ from θ for Facility Performance Categories I and II — ILS glide paths;

(b) 0·04 θ from θ for Facility Performance Category III — ILS glide paths.

3.1.4.3 *Coverage*

The glide path equipment shall provide signals sufficient to allow satisfactory operation of a typical aircraft installation in sectors of 8° on each side of the centreline of the ILS glide path, to a distance of at least 10 nautical miles up to 1·75 θ and down to 0·45 θ above the horizontal or to such lower angle at which 0·22 DDM is realized.

3.1.4.7 *Monitoring*

3.1.4.7.1 The automatic monitor system shall provide a warning to the designated control points and cause radiation to cease within the periods specified in 3.1.4.7.3.1 if any of the following conditions persist:

(a) shift of the mean ILS glide path angle equivalent to more than 0·075 θ from θ;

(b) in the case of ILS glide paths in which the basic functions are provided by the use of a single-frequency system, a reduction of power output to less than 50 per cent, provided the glide path continues to meet the requirements of 3.1.4.3, 3.1.4.4 and 3.1.4.5;

(c) in the case of ILS glide paths in which the basic functions are provided by the use of two-frequency systems, a reduction of power output for either carrier to less than 80 per cent of normal, except that a greater reduction to between 80 per cent and 50 per cent of normal may be permitted, provided the glide path continues to meet the requirements of 3.1.4.3, 3.1.4.4 and 3.1.4.5;

(d) for Facility Performance Category I — ILS glide paths, a change of the angle between the glide path and the line below the glide path (150 c/s predominating) at which a DDM of 0·0875 is realized by more than plus or minus 0·0375 θ;

(e) for Facility Performance Categories II and III — ILS glide paths, a change of displacement sensitivity to a value differing by more than 25 per cent from the nominal value;

(f) lowering of the line beneath the ILS glide path at which a DDM of 0·0875 is realized to less than 0·7475 θ from horizontal.

3.1.4.7.3 The total period of radiation outside the performance limits specified in (a), (b), (c), (d), (e) and (f) of 3.1.4.7.1 shall be as short as practicable, consistent with the need for avoiding interruptions of the navigation service provided by the ILS glide path.

3.1.4.7.3.1 The total period referred to under 3.1.4.7.3 shall not exceed under any circumstances:

6 seconds for Category I — ILS glide paths;

2 seconds for Categories II and III — ILS glide paths.

3.1.6 VHF marker beacons

3.1.6.1 *General*

(a) There shall be two marker beacons in each installation, except that a third may be added whenever, in the opinion of the Competent Authority, an additional beacon is required because of operational procedures at a particular site.

(b) The marker beacons shall conform to the requirements prescribed in this 3.1.6. When the installation comprises only two marker beacons, the requirements applicable to the middle marker and to the outer marker shall be complied with.

(c) The marker beacons shall produce radiation patterns to indicate predetermined distance from the threshold along the ILS glide path.

3.1.6.1.1 When a marker beacon is used in conjunction with the back course of a localizer, it shall conform with the marker beacon characteristics specified in Part I, 3.6.1.

3.1.6.1.2 Identification signals of marker beacons. used in conjunction with the back course of a localizer shall be clearly distinguishable from the inner, middle and outer marker beacon identifications, as prescribed in 3.1.6.5.1.

3.1.6.3 *Coverage*

3.1.6.3.1 The marker beacons system shall be adjusted to provide, when tested with a calibrated receiver and antenna, the following duration of visual indications at a ground speed of 96 knots when on the glide path:

(a) *Inner marker* (when installed): 3 seconds plus or minus 1 second.

(b) *Middle marker:* 6 seconds plus or minus 2 seconds.

(c) *Outer marker:* 12 seconds plus or minus 4 seconds.

3.1.6.5 *Identification*

3.1.6.5.1 The carrier energy shall not be interrupted. The audio-frequency modulation shall be keyed as follows:

(a) *Inner marker* (when installed): six dots per second continuously.

(b) *Middle marker:* a continuous series of alternate dots and dashes, the dashes keyed at the rate of two dashes per second, and the dots at the rate of six dots per second.

(c) *Outer marker:* two dashes per second continuously.

These keying rates shall be maintained to within plus or minus 15 per cent.

3.1.6.6 *Siting*

3.1.6.6.1 The inner marker, when installed, shall be located so as to indicate in low visibility conditions the imminence of arrival at the runway threshold.

3.1.6.6.2 The middle marker shall be located so as to indicate the imminence, in low visibility conditions, of visual approach guidance.

3.1.6.6.3 The outer marker shall be located so as to provide height, distance and equipment functioning checks to aircraft on intermediate and final approach.

3.1.6.7 *Monitoring*

3.1.6.7.1 Suitable equipment shall provide signals for the operation of an automatic monitor. The monitor shall transmit a warning to a control point if either of the following conditions arise:

(a) failure of the modulation or keying;

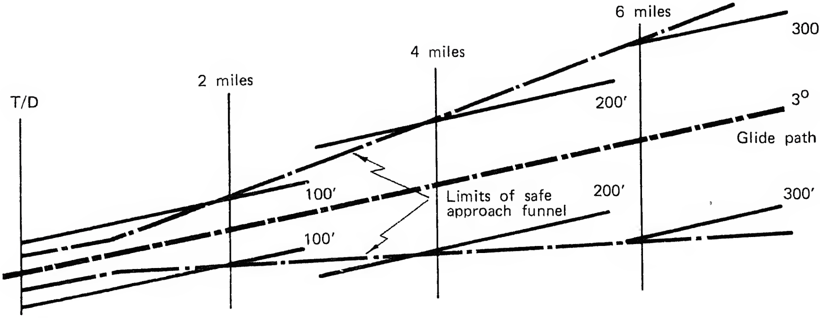
(b) reduction of power output to less than 50 per cent of normal.

Appraisal of the monitoring of an ILS approach by PAR in the vertical plane

(Note by Board of Trade)

Background

Monitoring of an ILS approach by PAR is purely an advisory function and at no time mandatory. Guidance and techniques to PAR controllers are laid down in paragraph 7.9 of ATCI (MATC 1). The Safe Approach Funnel is ±½° from the PAR nominal glide path (and 2° either side of the approach path in the horizontal plane). This ±½° is defined as displacement (in feet) above or below the nominal glide path and is shown in the diagram below. Also shown are the displacement lines which are optically projected onto the face of the radar display.



The PAR controller will not necessarily wait for an aircraft response to go outside the SAF but will advise the pilot if its movement away from the nominal glide path is such that it appears to the PAR controller the aircraft will shortly go below the funnel. Additionally if at any time the aircraft descends rapidly below the nominal glide path the PAR controller should advise the aircraft to maintain its present heights, or climb, according to the circumstances.

Presentation of elevation information in the vertical plane

The elevation beam on the T2000 scans through 7°; 6° above, to 1° below horizontal and, in scanning this vertical segment, the beam may be moved through a 20° arc in azimuth so as to follow any target on a changing bearing. The "beam" is nominally 3·0° wide and 0·4° high. A target could be expected to appear on the elevation scope about 0·4° "tall" and at, say, 4 miles will appear some 180 feet deep. Generally in practice it appears larger than this but may be reduced to some degree by continuous fine adjustment of the Sensitivity Gain Control. Size of target will not necessarily adversely affect controller assessment, his judgement of displacement being made by visually bisecting the echo and thus determining its position relative to the guide lines shown on his display.

To assist accuracy and to aid detection the 7° elevation cover is stretched vertically in a linear fashion by a factor of almost 9. Thus 7° appears as some 60°. Deviation of an aircraft target in the vertical plane may thus be more easily detected.

Re-fresh rate is on a shared basis with the azimuth display, each "sweep" in one direction taking approximately ½ second.

Sequence is: AZ left to right; EL up
AZ right to left; EL down

Thus, a new EL (or AZ) picture is provided each second. It should be noted that occasionally the up and the down sweep will not be coincident and the aircraft target may appear to jump.

Technique when monitoring ILS approaches

With a re-fresh rate of one new picture in each plane once per second a controller will scan both azimuth and elevation scopes alternately, obtaining a "history" of after-glow to reappraise him of the tendency with each sweep. The sharp deviation either from the glide path or the centreline (particularly from the glide path, as the centreline information is only expanded three-fold) will more easily register than a slow drift from an earlier trajectory.

The controller will monitor progress in both planes, noting displacements from either the glide slope or the extended centreline yet not necessarily intervening should a displacement be observed. In his advisory function he would only advise the pilot (in elevation) when rapid descent was observed or when the SAF was infringed.

Coupled with this monitoring role the controller will be passing range checks, requesting and obtaining a landing clearance and passing this to the aircraft together with any conditions of surface wind, change in RVR etc. When the aircraft is some 2–4 miles from touchdown in addition to continuing to monitor its approach he will be involved in receiving details of the next aircraft in the sequence from the director, establishing two-way R/T contact and informing this second aircraft that he will continue to monitor its approach. He must be prepared to step in at any part of the approach following an ILS malfunction or pilot request and, where possible, to continue the approach as a PAR "talk-down".

This technique is much different from that for a full PAR approach where such factors as drift and heading closure, rate of descent, pilot perception and reception to controller comment will be more positive. These all lead to a much higher certainty of success. Controllers too will only be concentrating on one aircraft, the succeeding one being held by the director until completion of the talk-down.

Factors concerned

Listed below are factors which would appear to influence the accuracy and adequacy with which ILS approaches can be monitored, and if necessary corrected, by PAR controllers.

1. Information display

(a) *Re-fresh rate*

One picture per second. The up-sweep may not be entirely coincident with the down-sweep.

(b) *Servo setting*

To follow aircraft in the final stages of their approach requires manipulation of the servo controls which may result in succeeding targets being temporarily lost.

(c) *Gain control*

Will be progressively decreased to preserve a small echo. Succeeding targets may be lost through this manipulation.

(d) *Precipitation returns*

Considerable skill is required to obtain the best viewing of targets passing through areas or "bands" of precipitation return which may obscure, or partially obscure, the whole, or part of the display.

(e) *Permanent echo clutter*

Normally not critical outside 1–1½ miles. Thereafter this will call for accurate servo and gain manipulation if targets are to be seen continuously throughout their approach.

2. Other tasks which can detract from the monitoring function

(a) *Liaison with radar director*

To determine sequence of aircraft to be monitored.

(b) *The patter in making two-way contact, together with advice on the intention to monitor.*

(c) *Language difficulties*

Standard R/T phraseology may be adequate for standard instructions amongst English speaking air-crew. However, with foreign operators delay and difficulty can occur in "putting across" guidance information.

(d) *Passing of clearance to land*

There are occasions when this is slow in forthcoming (traffic slow to roll or to clear the runway). Use of the PAR liaison line may be necessary.

(e) *Passing of surface wind and other information*

(f) *Passing of advice*

Where much advice is passed on one plane of guidance some distraction could occur within the other plane.

3. Appreciation and interpretation of radar data

(a) *Time before displacement is detected*

With a re-fresh rate of one frame per second the first deviation from the glide path (even in the event of gross change in flight profile) could not be detected. The second paint could possibly be spotted though, with any other distraction, it would not be noted. The third sweep, provided there was not too much lack of synchronization between up and down sweep, would provide the controller with his first detection — with poor synchronization it could easily be the fourth or the fifth sweep.

Again, assuming no distraction, he would obtain information from a further two or three sweeps (ie the seventh or eighth sweep) before becoming convinced that corrective action was, or was not, required.

A further 2 seconds could well be taken in issuing the necessary corrective advice. Thus, 9–10 seconds could elapse before the pilot was first advised of his displacement.

(b) Upon the issue of corrective advice the controller could well await a further two or three sweeps to ascertain whether this advice was being acted upon (ie 11 or 12 seconds from the time of the initial displacement). Further advice on displacement would then continue to be issued. These are realistic time intervals. In the event of difficult conditions, distractions, corrections being given in the other plane (ie azimuth) and so forth it could be considerably longer.

This background information highlights the delay factors which will affect the initial warning of deviation, ie the PAR controller section of the loop.

From that point a further time lag will occur whilst the following actions and sequences take place in the cockpit:

(a) *Time of register*

The meaning of the PAR advice must register and it may take more than one transmission, of an increasing urgency, before this is understood — remembering that other standard information is being broadcast.

(b) *Appreciation*

The PAR message must be fully understood and the magnitude of the displacement information must be appreciated. Foreign operators may have relatively large "delayed response" time owing to language difficulties.

(c) *Conviction*

Having "got the message" the pilot will carry out cross checks. With his technical knowledge he will weigh up the information presented to him by other instruments and decide the credibility of the PAR controller's message.

(d) *Reaction*

Having been convinced he will react by deciding what recovery action he should take. This may vary from a minor adjustment to discontinuing the approach and initiating missed approach procedure.

The sum of these delays in the cockpit must then be added to the PAR controller delay and the overall time taken will then provide the instant at which corrective action is initiated to retrieve the situation.

The table below shows descent rates along a 3° glide path at various ground speeds. Also shown is the height loss over varying periods of time when descent is made along this glide path.

Ground speed kts	*Descent* f.p.m.	*Loss of height after*				
		10 secs	12 secs	15 secs	20 secs	30 secs
120	636	106	128	159	212	318
140	742	124	149	186	247	371
160	848	142	169	212	283	424
180	954	159	191	239	318	477

In formulating examples as to what the time factor will be for correction of aircraft with high sink rates, it becomes difficult and perhaps unrealistic to include all the adverse factors in a single example.

However, the table below provides a time scale for one straight forward set of circumstances. It is postulated that an aircraft is making an ILS approach at a ground speed of 160 knots. The descent path is suddenly increased to 6° (ie 3° below the glide path). PAR is functioning normally and the controller has no undue distractions. This time scale is listed at various ranges from touchdown.

Range from T/D	1 ml	2 ml	3 ml	4 ml
3° G/P SUBTENDS	318	636	954	1272
If descent is at 6° G/S 160 then height at which PAR controller "puts over" message	—	297	615	933
REMAINING time for pilot appreciation, correction etc.	—	10 secs	22 secs	32 secs

In the table above a delay time of 12 seconds has been assumed before the PAR controller provided his first advice on deviation. It is only within the scope of conjecture, and outside this note, to decide how long the pilot would take to register and react to this advice and then to add the time for corrective action initially to halt the well-established sink rate and then to correct the error which will have become magnified.

APPENDIX 4

Frequency of requirements of approach aids

The following tables summarize the requirements for approach aids. The data have been determined as follows:

a = number of occasions when cloud was $\frac{5}{8}$ or more, base 450 feet to 600 feet and/or visibility between 1000 and 1800 metres.
b = number of occasions when cloud was $\frac{5}{8}$ or more, base 100 feet to 449 feet and/or visibility between 400 and 499 metres.
c = average hourly aircraft movements for the year 1969 (landings).
d = movements c × occasions a
e = movements c × occasions b

An analysis has been made on an hour to hour basis to determine the quantities d and e for Heathrow, Manchester and Gatwick, the values of the meterological factors a and b being determined by averaging over the past 10 years for Heathrow and the past 5 years for Manchester and Gatwick. The columns $(d + e)$ in the following tables represent the total number of landings requiring ILS whereas the column for the quantity e (being based on meteorological conditions b rather than a) represents landings below the limits for approach aids like NDB.

Monthly and Annual Instrument Approaches Expressed as a Percentage of Total Landings
London (Heathrow) Airport

Month	*Total landings*	(ILS/PAR + NDB) $(d + e)$ *Instrument approaches*	*Percentage of total landings*	(ILS/PAR only) (e) *Instrument approaches*	*Percentage of total landings*
January	8,665	1,647	19·00	572	6·60
February	7,729	1,275	16·50	375	4·85
March	9,026	856	9·48	168	1·86
April	10,467	847	8·09	170	1·62
May	11,732	298	2·54	61	0·52
June	12,275	416	3·39	67	0·55
July	13,390	319	2·38	52	0·39
August	13,011	533	4·10	116	0·89
September	12,573	1,008	8·02	301	2·39
October	11,437	1,273	11·13	353	3·09
November	9,505	1,365	14·36	469	4·93
December	9,229	1,612	17·47	540	5·85
Year	129,039	11,449	8·87	3,244	2·51

Monthly and Annual Instrument Approaches Expressed as a Percentage of Total Landings
London (Gatwick) Airport

Month	*Total landings*	(ILS/PAR + NDB) $(d + e)$ *Instrument approaches*	*Percentage of total landings*	(ILS/PAR only) (e) *Instrument approaches*	*Percentage of total landings*
January	2,388	548	22·95	246	10·30
February	2,240	307	13·71	101	4·51
March	2,698	258	9·56	39	1·45
April	3,693	296	8·01	73	1·98
May	4,178	182	4·36	47	1·12
June	4,925	309	6·27	97	1·97
July	5,307	320	6·03	69	1·49
August	5,210	451	8·66	141	2·71
September	4,768	369	7·74	133	2·79
October	3,503	313	8·94	92	2·63
November	2,336	288	12.33	97	4·15
December	2,383	396	16·62	147	6·17
Year	43,629	4,037	9·25	1,282	2·94

Monthly and Annual Instrument Approaches Expressed as a Percentage of Total Landings

Manchester Airport

Month	*Total landings*	(ILS/PAR + NDB) (*d* + *e*) *Instrument approaches*	*Percentage of total landings*	(ILS/PAR only) (*e*) *Instrument approaches*	*Percentage of total landings*
January	1,651	251	15·20	86	5·21
February	1,386	136	9·81	53	3·82
March	1,938	66	3·41	20	1·03
April	2,140	68	3·18	23	1·07
May	2,457	38	1·55	13	0·53
June	2,829	55	1·94	16	0·57
July	2,785	96	3·45	34	1·22
August	2,685	86	3·20	32	1·19
September	2,608	136	5·21	52	1.99
October	2,266	145	6·40	57	2·52
November	1,742	144	8·27	55	3·16
December	1,497	231	15·41	85	5·67
Year	25,986	1,452	5·59	526	2·02

APPENDIX 5

Opinions of airline operators

(Extracts from the operators' letters to the inquiry)

Aer Lingus

Aer Lingus have never had a policy requiring ILS approaches to be monitored on PAR. This practice evolved largely because the facility was not available at a majority of the airports to which we operate. Further, we would not see a requirement developing to provide the facility in the future although we believe that certain air safety improvements could be effected where approaches are monitored in a routine way. We would see a particular requirement where parallel approaches are being made in instrument conditions and the problem of a mistake in frequency selection arising. We further believe that some cases of gross error might be prevented if there were a timely intervention from a monitor. We are aware of aircraft hitting the ground at a considerable distance from the runway and in some of these cases it would seem that a monitor system might have prevented an accident.

We are conscious of the need to provide the pilot with information both on local traffic and, particularly, RVR in the final stages of approach and would feel that the operational requirement is greater for this item than is the requirement for radar monitoring.

In summary, then, we would state our policy as not requiring additional facilities to be provided for radar monitoring but recognizing that where the facility is available, some contribution to overall air safety is effected.

Aerolineas Argentinas

We are pleased to advise you that our airline recommends the provision of PAR at the United Kingdom airports used by our aircraft.

The provision of precision approach radar will undoubtedly reduce the risk of accidents by furnishing pilots with highly accurate navigational guidance.

The reasons to hold our views are those already expressed by our airline and most of the operators, as well as airport authorities, airline pilots associations, IATA and other members of the industry on this question.

Air Canada

We believe that each case should be considered on its own merits. The relevant factors that must be taken into account include:

(1) The effectiveness of the ILS equipment.

(2) Reliability of the ILS installation, including the availability of a standby installation.

(3) The possibility that the precision approach radar may be required for monitoring operations on parallel runways.

Air France

It is most certain that gross errors (malfunction, erratic signals . . .) resulting in premature let-down over topographical features may be avoided through the use of PAR monitoring. In that way PAR is a very valuable means.

In the later part of the approach, global performance of the "system" is more closely related to the techniques applied and understanding between the flight crew and the controller. When good operating techniques are used and clear understanding exists, PAR monitoring can bring significant improvement to the safety of ILS approaches, otherwise it might rapidly become a burden to the crew.

We feel that it is not possible to state a general policy applicable to all locations. When planning implementation or withdrawal of a PAR facility, consideration should be given to topographical features, reliability of ILS facilities, occurrence of unfavourable met conditions etc. . . .

Furthermore, the use of PAR can bring additional benefits for traffic sequencing and localization of a disabled aircraft.

Air-India

While Precision Approach Radar is a reliable aid for monitoring the approach of an aircraft making an

ILS approach, pilots do not normally request for PAR monitor, as they rely more on the airborne equipment. If a decision to withdraw PAR facilities is made on grounds of inadequate use and costly maintenance, we have no objection for their withdrawal.

With regard to ILS, our experience has so far indicated that the ILS equipment at London (Heathrow), Gatwick and Prestwick are maintained to a high standard.

Alitalia

The opinion of our Company is that in consideration of the poor reliability and integrity of some ILS systems in operation at present, the PAR monitor remains a desirable aid from a safety view point.

The importance of the PAR will probably diminish with the advent of new systems that will permit to continuously check from the ground any ILS malfunction and immediately pass on this information to the Pilot.

In light of the above it can be said that the advisability of the PAR services is dependent from various factors, amongst others, the availability and the reliability of other radio aids at a particular airport (for instance DME in conjunction with ILS LOC), the orographic features of the area, the availability of standby transmitter, etc.

Austrian Airlines

Austrian Airlines so far had no complaints concerning the ILS-system at London (Heathrow). However, as the use of providing PAR monitoring would increase the safety of the flight, the Austrian Airlines will appreciate this intention.

Autair International Airways Ltd

It is our view that the need for PAR Monitoring of ILS approaches will remain for some time to come as a factor in reducing the accident risk.

There have been three recently reported incidents and one accident in which PAR Monitoring would have detected the errors in the ILS flight path.

We have ourselves experienced a malfunction of aircraft equipment whilst on an ILS approach, into Heathrow, which was very quickly picked up by the radar monitor.

Balkan Bulgarian Airlines

Having in mind the experience of our crews in the use of the Instrument Landing Systems at aerodromes and the views expressed, we would consider:

(1) The instances of failures of ILS-systems, either or partial occur frequently, leaving the PAR as the only reliable means for air navigation in bad meteorological conditions as well as during night flights.

(2) According to the methods for determining in approach procedures and minimum safety altitudes (terrain clearance) in airport areas, the safety standards when PAR is used are considerably lowered or close to those of the most precise ILS systems. This factor serves as a guarantee for the safety and capacity of the respective aerodrome, as it appears in document 8168-OPS/611-Air Navigation Services, II ed. 1967 of ICAO.

(3) Our practice shows and medical inference confirms, that an experienced PAR-operator can in most cases notice any deviation from the aircraft's course and reacts sooner than the pilot himself, as he has to check not only the air navigation equipment, but also the other instruments indicating the engine's and plane's functioning.

(4) The improvement of ILS systems does not exclude the use of PAR, at least in the coming 10–15 years. PAR remains among the fundamental approach and landing equipment for the time being.

The presence of PAR at an aerodrome increases the safety of the flight in the aerodrome region and its reasonable use will almost in all cases provide for a successful approach procedure for landing and a safe landing.

British Air Ferries

It is the opinion of the majority of pilots in my Company that there is a need for radar monitoring on all types of instrument approaches, but especially ILS approaches when operating to absolute minima.

The reasons being as follows:

(1) The occasion when a pilot is carrying out an ILS to absolute minima is frequently at the end of a days duty.

(2) Less strain is placed upon the pilot when he is being Radar Monitored.

(3) When Radar Monitoring is taking place the pilot *not* carrying out the ILS can relax his monitoring slightly in order to carry out other checks and visual checks for approach lights, etc.

(4) In the case of certain older types of aircraft with unsophisticated equipment, which is not so reliable as modern equipment, Radar Monitoring is essential in case of failure. This also applies to aircraft having only one ILS installation.

(5) Radar Monitoring, from experience, is an additional safety factor and must therefore be considered essential.

Finally, from my own point of view, until such times as ground and airborne equipment become 100 per cent reliable radar monitoring is a "must". Any form of assistance which can reduce the mental strain during the most hazardous part of the flight is very much an essential.

British European Airways

It is our view that a properly operating ILS, with adequate standby facilities, is the best method of making an instrument approach to landing. It was with this in mind that we have agreed to the withdrawal of existing PAR facilities, providing that satisfactory ILS approach facilities are available.

Following on from this point, it is our view that there is no requirement for PAR monitoring for the following reasons:

(a) The preferred method of achieving a high level of safety during an approach to land is through properly designed crew procedures, and the provision of fail-safe and fail-operative equipment in the aircraft and on the ground.

(b) In some cases the airborne and ILS equipment and the PAR equipment may be operating within tolerances but differing to the extent that although the approach is perfectly safe, intervention by the PAR controller would be called for, and this could distract the crew from the primary monitoring tasks.

(c) PAR monitoring has no role to play in the very low visibility operations, because of the high level of integrity and performance demanded of an automatic system, and the associated monitoring facilities provided in the aircraft.

(d) The cost effectiveness of PAR is very low and there are many areas where money could be spent to better advantage in raising the level of safety.

A special case arises for independent landings on parallel runways, eg Heathrow. Today, and for some time to come monitoring in azimuth will be required in view of the separation distance between the runways and the extended centre-lines. At the present time the only satisfactory azimuth monitoring is by means of the azimuth element of the PAR equipment. We know that developments are in hand in relation to plan position indicator equipment but pending a suitable one becoming available for operational use, there is a requirement for PAR monitoring in azimuth in these circumstances. We understand that work is in hand with the object of being able to do this with a single PAR equipment to obviate the need for two equipments and crew to monitor each centreline independently.

In summary, therefore, we see no need for PAR monitoring when the ILS is promulgated for operation to appropriate ICAO standards, but we do see a continuing need at this time for azimuth monitoring in relation to independent parallel approaches.

British Midland Airways

It is the opinion of the pilots of this Company that PAR monitoring of ILS approaches must reduce the risk of accidents.

PAR monitoring provides a complete cross check of the approach path, by an approach aid which is of similar accuracy to ILS, using information derived from a different source, and being interpreted by an operator who is not distracted by the need to monitor other systems. It is also useful to be able to switch to another approach aid of similar accuracy, should the reliability of the ILS become in doubt during an approach.

British Overseas Airways Corporation

Any differences of opinion within BOAC are generally associated with a wider consideration of the requirement than "to monitor as a means of reducing the risk of accidents, the flight path of aircraft making an ILS approach". Within this narrow field of requirement our contribution cannot be a great deal more than judgement. Ideally it should first be established that PAR as a monitor does reduce the risk and that this risk reduction can be justified economically (cost benefit ratio).

However, our experience is that ILS is highly reliable. We cannot find on the record any international accident where the cause, wholly or in part, was related to the ILS equipments. Even so, there is evidence to indicate that aircraft have not followed the

ILS flight path. In this context it could be said for PAR that:

(a) It will provide a check against altimeter missetting and could perhaps in the extreme case prevent an aircraft flying into the runway in fog, the pilots thinking that they are still approaching their minimums. The check on height passing the outer marker is not accurate enough for this purpose.

(b) In hazardous approach environments in IFC in particular, when pilots cannot provide a personal check, it gives a degree of confidence which is conducive to adherence to the ILS in both the vertical and horizontal planes. Additionally, it acts as a deterrent against pilots deliberately going below minimums when not visual.

(c) It would guard against the remote possibility of the pilots continuing the descent to the ground if their attention was suddenly distracted by a serious emergency in the final stages of an approach.

(d) It would guard against the possibility of the pilots failing to detect a glide slope failure.

In the foreseeable future parallel runway approaches will be a common feature of high traffic airports. There is some evidence that ILS or some other approach development would facilitate a relatively close runway configuration and/or close lateral spacing of aircraft on the approach paths.

It is our judgement that low separation standards will bring a measure of automation which, with the human pilots still in command, will dictate an independent flight path check. It would certainly facilitate pilot acceptance of associated automation and close proximity of aircraft.

To what extent PAR does or can be developed to meet this future requirement is beyond us. We note that other surveillance radar does not include a vertical plane check.

As we see it this monitor function would be continuous and silent except when the aircraft departed from the ILS flight path.

One other aspect of the present PAR is that it enables an airport to stay open in particular weather conditions when ILS is unserviceable.

Our conclusion, therefore, is that because we see a future monitor requirement, however vague at this time, and because of the general support role of PAR in different existing environments, we would suggest its retention until any future requirements have been thoroughly considered and finalized.

Cambrian Airways

Briefly summarizing our views, we are of the opinion that the PAR system should no longer be necessary when an accurate approach system is installed.

Ground and airborne ILS equipment reliability is of a high order and in the case of airborne equipment, normally duplicated.

The interpretation time lag involved with PAR is such that a departure from the glide slope at the more critical phase of the approach would not be recognized in time to be effective in preventing an accident.

This point of view could be disputed following the recent incident at Manchester, but we would not regard this particular incident by itself as a reason for retaining PAR.

Dan-Air Services Ltd

In principle I believe that the provision of any aid that offers additional safety is justified. I think that the installation of this equipment is necessary.

El Al Israel Airlines

We are in favour of PAR as a monitor for ILS approaches for these reasons:

(1) The additional safety factor provided by PAR monitoring in case of cockpit instrument failures, or wrong indications either by the cockpit instruments or by the ground ILS installation. These failures and/or wrong indications are not always readily detectable by the failure indications built into the aircraft systems, and any additional cross check is valuable.

(2) The increasing use in present and future aircraft of automatic approaches, while freeing the pilot from some of the physical load of flying the aircraft, still makes heavy demands from the point of view of cockpit management, so that the additional aid provided by PAR monitoring can only be beneficial.

(3) The psychological benefit to the pilot, knowing that his approach is being followed closely by the PAR monitor, is, in our opinion, a positive factor, in that he knows that an additional cross check on the accuracy of the approach is being carried out.

Finnair

According to our experience the ILS equipment in general has been reliable.

We know only about one case where our Caravelle made an ILS approach with autopilot (All Weather Landing) and where the autopilot captured and locked on to the split beam of ILS glide path. Due to this the landing was not possible as the aircraft had too much height when passing the Outer Marker.

If all approaches are PAR monitored it will delay the traffic at busy airports.

The most important argument in favour of PAR is that it helps to recognize pilots' human errors and thus reduces the risk of accidents. Therefore, we consider the providing of PAR desirable.

Icelandair

In case of failure during an instrument approach, either in the airborne equipment or in the ground equipment we feel that a PAR monitored approach would be safer as the crew could be alerted immediately if the aircraft wandered off course or glide path. An approach under such circumstances could even be continued in safety under PAR instructions, instead of making a missed approach and possibly diverting to an alternate airport.

Icelandic Airlines

We have no strong feeling about the matter. Without doubt the monitoring of ILS approaches by PAR is an additional safety factor and the use of this combination is in our opinion the ideal procedure.

We must, however, consider that a properly operated and maintained ILS provides adequate guidance to the pilot to enable him to make approaches down to the prescribed minima in full safety.

Japan Air Lines

Our view about the need for PAR monitoring during ILS approaches is the same as the one expressed in ICAO Doc. 8588, EUM/V 3.1.4.10:

"While GCA was a valuable aid to monitor ILS approaches by aircraft, its provision was not considered adequate to permit a reduction in the weather minima. In view of this situation, no additional requirements for the provision of this installation were put forward. In fact, it was pointed out that, because of its high initial installation cost and the considerable current expenses required for the continued operation of such a facility, it may not be the best possible investment in order to improve reliability of operation at a particular aerodrome."

KLM Royal Dutch Airlines

We do not believe that a firm yes or no can be given, as the necessity of providing a PAR facility varies considerably from location to location.

The main factors to be considered are the topographical and meteorological conditions, the accuracy and availability of the ILS equipment, the availability of stand-by equipment and the type of traffic.

We do believe however, that where simultaneous approaches on parallel runways are contemplated, a PAR would provide an essential monitoring function. Our experience indicates that since the PAR was decommissioned at our home base, Schiphol Airport some time ago, we have never felt it as a loss.

Kuwait Airways

Although present day Instrument Landing System equipments are very accurate, most of our pilots, it was found, are in favour of having Precision Approach Radar to monitor the flight paths of aircraft making instrument landing system approaches as a back-up and cross check to the ILS.

Even with the most modern equipment as we have on our Boeing aircraft complete failure of the ILS did occur and approaches made solely on PAR monitoring.

Loganair

The nature of our operations here is such that we seldom make contact with either PAR or ILS. However, it occurs to me to observe that, if it is judged necessary to monitor an aircraft's ILS approach by the use of PAR, there would appear to be little justification for retaining ILS since its advantage of being pilot-interpreted and thereby obviating the expense of PAR operating staff and equipment would be negated or reduced. Why not just make all approaches on PAR and save the cost of ILS equipment? It may be, of course, that logic bred from operating a subsonic BN2 Islander in the crowded stack of Orkney's Terminal Control Zone is not really applicable to the less intense traffic of Heathrow, Gatwick and such like.

Lufthansa

We consider ILS on its own to be the primary aid for the conduct of an instrument approach-to-land and, as a general rule, have no requirement for the monitoring of an ILS approach by PAR.

Although we fully recognize the benefits which can be derived from the use of PAR on runways where no ILS is installed, there are certain limitations inherent in the PAR system which do not render it suitable as an adjunct to improve the current ILS, ie the time lag existing between a discernible deviation being observed by the PAR controller, appropriate information being furnished to the pilot and corrective action being taken by the latter, if found necessary.

Consequently, where PAR is installed and is used to monitor ILS approaches, this has no bearing on the aerodrome meteorological minima established by this Airline for such approaches. However, there may be special circumstances which would render the availability of PAR for monitoring purposes desirable, such as the reliability of the ILS ground installations, the lack of standby equipment and emergency power supply.

In our opinion there is a need for the availability of PAR monitoring whenever simultaneous approaches are conducted using parallel runways, ie for purely ATC purposes.

Luxair

For our type of equipment we do not consider PAR essential, although we do regard it as a desirable back-up.

Our reasons for this view are:

(1) Whilst we do not have any actual statistics on the reliability of ILS, we are generally satisfied with its performance.

(2) We feel that whilst a pilot is making an ILS approach, the distraction of incoming RT communication should be kept to a minimum.

Libya Airlines

Our chief pilot, Caravelle fleet comments that, theoretically a good ILS is sufficient to give a safe descent slope, the spacing of aircraft being ensured by SRE or PAR.

On the other hand PAR can be extremely useful in case of total or partial failure of the ILS, or during its maintenance periods.

He considers as desirable the installation of PAR on main airports for slope surveillance and rapid traffic flow.

Malev Hungarian Airlines

This time there is no need for precision approach radar in Hungary from our part and we are not planning purchase or use of this type for the next future. In case of any requirement we do not hesitate to contact you with corresponding informations in duly time.

Pakistan International Airlines

In our viewpoint it cannot be taken as a general principle if PAR facility is required to monitor as means of reducing risk of accident, but it requires a detailed study for its requirements at an individual airport.

The following points are of primary importance:

(1) The effectiveness of the ILS equipment.

(2) The reliability of ILS installation and the availability of stand-by installation.

(3) Such topographical or environmental conditions of a particular airport justifying the use of ILS and PAR.

(4) The possibility that PAR may be required for monitoring operation on parallel runways.

We are using quite a high landing minima at London Heathrow airport, ie 300–¾ for ILS and PAR. In view of this minima, although a PAR facility may not be required for our operation but due to the high traffic and the parallel landings we feel that PAR is a must requirement as a means of reducing risk of accident.

Pan American World Airways

It is the position of Pan American that Precision Approach Radar is not required to assist or monitor its aircraft while making instrument approach landings using an Instrument Landing System. Our aircraft, used in conjunction with an approved Instrument Landing System, are equipped with redundant instrument warning systems which combined with specified operating procedures, make PAR a redundant requirement.

Quantas

Our view is that we could not justify the retention or installation of PAR facilities at airports where ILS exists unless there is terrain which could justify the monitoring of ILS approaches. Hong Kong is an example of such an airport.

At ILS equipped airports where no terrain problem exists, we believe that the key to safe operation is proper monitoring of cockpit instruments, particularly the altimeter, with a decision to overshoot from the approved minimum height, rather than descend below this level, unless the aircraft can clearly land visually.

Scandinavian Airlines System

We do not think that PAR shall be provided for the sole purpose of monitoring ILS approaches. Where a PAR is operated for other reasons, it should also be used for monitoring.

Our opinion is based solely upon cost/effectiveness reasoning.

PAR-monitoring of all ILS approaches would undoubtedly reduce the risk of accidents. However, PAR is costly to operate. We believe a similar improvement in safety can be achieved at lower cost by investment in other projects.

One such closely related other project could be for instance installation of effective altitude alerting systems in transport aircraft. PARs are generally paid for by airport authorities and aircraft installations by aircraft operators. We find the comparison relevant anyway. In the end all costs are liable to be paid by the transport system's users.

Seaboard World Airlines

We think that PAR is of no value in collision avoidance for single ILS approaches, however, in our opinion, it is of value where parallel ILS approaches are conducted.

Sierra Leone Airways

Our United Kingdom Schedules are operated for us by British United Airways, who, no doubt, will be forwarding their own comments.

There is no ILS in Sierra Leone, and it is therefore regretted that we can be of no assistance in your enquiry.

South African Airways

South African Airways is strongly opposed to the withdrawal of PAR from any international airport or its alternate where prevailing local weather conditions influenced the original installation.

Although it is fully appreciated that the ILS serviceability, reliability and precision has improved steadily over the years to the extent that today it is virtually infallible, and, although the principle of treating ILS as the *primary* landing aid is firmly established in this airline, we believe equally firmly, that PAR is a valuable monitor, particularly at congested airports.

It is a proven method of speeding up traffic flow, reducing delays, minimizing the possibility of diversion caused by delays and it very definitely reduces the risk of accidents.

At an aerodrome like London (Heathrow) Airport, for instance, where parallel landings are practised and will in all probability be a definite requirement soon, we think that PAR is indispensible.

A factor not to be overlooked is that although ILS ground and airborne equipment have earned a wonderful reputation for serviceability they do fail sometimes. In this predicament PAR is a wonderfully comforting piece of equipment.

Finally, in the case of a sudden emergency such as an engine fire after take-off (vide the BOAC B707 at London Airport) PAR can be of immeasurable assistance to the pilot to get his aircraft down quickly and safely in bad weather.

Sudan Airways

I strongly recommend the maintaining of this aid and any other aid which contribute to more safety.

Swissair

PAR will never again be as good as ILS is, due to time delay between appearance on the screen, transmission time and the corrective action of the pilot. For this reason WX Minima for PAR approaches are higher than for ILS, which becomes important on short final where obstacles are close and tolerances become very little.

PAR-training on ground and in the cockpit is very low, since ILS is practically used everywhere.

Wherever there is a full ILS equipment existing, there is little use for PAR, except in special cases. The ILS equipment on ground and in the air with its respective monitoring systems proves to be so reliable that no additional monitor is required.

PAR can, however, serve a useful purpose for monitoring a/c during the intermediate approach. Furthermore, it is very useful for the same purpose at London Airport during parallel approaches because the separation of the runways is rather small.

Trans World Airlines

TWA concurs with a recent assessment of PAR by the International Air Transport Association. IATA concluded that Precision Approach Radar is secondary to ILS and therefore cannot be justified in the category of an operational requirement. Also identification and positioning of aircraft are obtained through the extensive use of terminal area radar.

For these reasons we would not object to the withdrawal of PAR facilities when full ILS has been installed and satisfactorily tested.

Varig

We consider undoubtedly, that the ILS remains the primary landing aid at International aerodromes, and it would therefore appear that the decision to retain or install a PAR is likely to adversely affect the performance of the ILS. Thus priority should definitely be given to ensuring the highest possible standard of operation of the ILS concerned.

PAR is now of less interest in view of the widespread use of ILS, and no operational disadvantage was apparent at those locations with ILS existing, and where PAR service had been discontinued.

APPENDIX 6

Opinions of United Kingdom airport authorities

(Extracts from the Authorities' letters to the Inquiry)

British Airports Authority

Under the Airport Authority Act, 1965, the Authority is precluded from providing navigational services except with the consent, in writing, of the Minister.

The Authority has been granted a dispensation to provide airfield lighting but the provision of Precision Approach Radar rests with the Board of Trade as the provider of Air Traffic Control and the associated telecommunications facilities. Thus the authority has no direct interest in providing Precision Approach Radar. On the other hand, the Authority is most interested if its availability affects either the safety or efficiency of operation of the airports for which it is responsible.

From the safety point of view. Precision Approach Radar permits Air Traffic Control to monitor an aircraft making an approach on the Instrument Landing System and advises the pilot if his approach path, particularly in elevation, shows any appreciable deviation from the optimum. By this means it can contribute towards the safety of operation at an airport.

In addition, PAR allows a pilot of a non-ILS equipped aircraft or one on which the airborne installation is unserviceable to undertake an approach in lower weather conditions than would otherwise be the case. By the same token this can contribute towards both safety and efficiency of operation.

The incidence of overshoots is greater during conditions of low cloud and poor visibility than in good weather. Overshoots by their nature can adversely affect the movement rate at an airport. This is extremely important during busy conditions. The availability of PAR to monitor ILS approaches should reduce the incidence of overshoots which are frequently a difficult task for pilots.

It is inevitable that from time to time ILS installations, either localizers or glide paths, have to be withdrawn from service for maintenance purposes. In addition from time to time it is necessary at an airport to extend a runway or to undertake other work on the runway or its associated facilities which will affect the operational efficiency of ILS. In many instances this entails the withdrawal of the ILS service. The non-availability of ILS can affect the operational efficiency of an airline or an airport, particularly one with a single runway. On the other hand the availability of PAR, which generally speaking will not be affected by works programmes, enables a service to be given on those occasions when the ILS is not available or a better service when a localizer has temporarily been installed in an offset position.

Finally, the Airport Authority is very concerned to contain the aircraft noise problem, and PAR is the only means available to the Board of Trade to monitor the height of aircraft approaching the airport, which enables inaccurate claims to be refuted that aircraft are approaching the airport too low. Without this information it would be very difficult for both the Airports Authority and the Board of Trade to contain the noise complaints which arise from districts under the flight path of aircraft approaching an airport such as Heathrow or Gatwick.

Birmingham

First, it will be appropriate to point out that the navigation services, including approach aids, are provided by the Board of Trade under a 21 year agreement between the Corporation and the Board of Trade. In the circumstances, the board determine the equipment to be provided at this airport, but this does not preclude the Corporation from making representations about the provision and installation of technical facilities.

Secondly, in answer to the particular enquiry on the need for Precision Approach Radar (PAR), the Airport Director is of the opinion that some purpose is served by the provision of this aid, but this must be related to a number of factors including the desirability, or otherwise, of duplicating the approach facility and whether the cost can be justified. It is simple to say "safety at any price", but it is questionable how much additional safety is achieved by monitoring ILS approaches with PAR. Furthermore it is necessary to take into account the high approach speeds and rate of sink of the latest types of turbo-jet aircraft and whether after receiving advice from the Air Traffic Controller, the pilot has time to take corrective action within the available height above ground level.

Although the enquiry does not call for comment on the reliability of ILS equipment the Airport Director considers it essential to refer to this aid in relation to the enquiry about the provision of PAR, because he is of the opinion that it is essential that the serviceability and integrity of ILS should be of the highest order and if this is achieved the need for PAR is secondary.

Blackpool

I have to state, firstly, that this airport is not equipped with ILS and I am, therefore, unable to speak from experience at Blackpool on the reliability of this equipment. Consideration has, however, been given in forward planning to the provision of ILS and you may therefore be interested in the views of an airport in this position.

The terms of reference of your inquiry imply that it is necessary to seek a means of reducing the risk of accidents to aircraft making ILS approaches. It is known, statistically, that most accidents occur in the final stages of an instrument approach, including the flare and touchdown, and this factor has to be considered against the obvious operational advantages of an ILS system.

The current generation of high-performance aircraft appear to have a propensity for undershoot tendencies, coupled with a requirement for more and more concrete. For a typical non-State airfield I believe that a requirement to provide PAR monitoring of ILS approaches would not only be so prohibitively expensive as to jeopardize the decision to install ILS, but would also not necessarily be justified from the safety viewpoint. One of the advantages of ILS, from an administrative aspect, is that the aid is pilot-interpreted. PAR would achieve almost the same weather minima and, if required, might just as well be the primary aid.

A non-State airfield is, of course, just as safety conscious as any other, but it is probably more cost conscious, particularly when it is responsible for its own technical services.

A good deal has been said and written on the need to provide a pilot with earlier indications of his approach to the high-sink rate, undershooting conditions. I would not presume to infringe on this expert field but, as the person responsible for advising the aerodrome authority, I believe that the solution to this problem lies in technical improvements under the following three headings:

Improved aircraft performance in this critical phase.

Instrumentation to improve the pilot's awareness of the critical flight envelope

Improvements to the ILS glide slope to provide more accurate information down to touchdown.

Bournemouth

In order to reach any decision on the desirability of PAR as a monitor system, it is necessary to assess the shortcomings, if any, of ILS. Although the modern ILS is a most reliable system electronically, benefiting as it does from the almost universal application of solid-state circuitry, there are still many older equipments in use which are subject to the inherent disadvantages of older techniques. These comments of course, apply both to ground and airborne equipment, but, in addition, the airborne equipment is subjected to shock, vibrations, etc, all of which affect the serviceability of the installation and which, overall, can result in an unsatisfactorily low mean time between failures.

Although long term beam deflection problems can be taken care of during initial installation, short term bending can occur, which, by means of monitoring devices, will not allow the ILS to be operated outside accepted limits, but which can result in an equipment shut down, possibly during the course of an ILS approach. Interruptions of the beam have the same effects.

From a safety viewpoint, it is not unknown for a pilot to be distracted during an ILS approach, resulting in major deviations from the intended flight path and the availability of PAR is a means of drawing the pilot's attention to such deviations before the safety of the aircraft is involved. Additionally, in the event of any interruption of the ILS during an approach the PAR controller is able to take over and the approach continued as a normal talk down.

Because the confidence and, thereby, the efficiency of the pilots must be enhanced by the knowledge that approaches are being monitored by a proficient controller, and for the reasons stated above, it is my opinion that the withdrawal of PAR was a retrograde step and that this is a situation where financial stringency must not be allowed to outweigh the safety of passengers and aircraft.

It is also my opinion that with the advent of the very large aircraft about to be introduced into service, a completely independent, ground based, monitor system is very desirable, if not essential, during the ILS category II and III operations entailed, despite the inherent safety of duplicated and triple fail safe systems. An extra man in the loop will provide safety benefits far in excess of the cost of providing him.

Bristol

There is little doubt that where monitoring can be effected this is a commendable situation on the grounds of safety. A second and independent source of information on the approach path of an aircraft is only following an established pattern of check and cross check on all phases of flight.

It would, however, be unreasonable to mandatorily require the installation of PAR in order to utilize ILS, and if statistics prove that ILS is unreliable, then approach minima should be raised sufficiently to cover this degree of unreliability.

It is to be hoped that your terms of reference do not reflect a policy of acceptance of ILS as the ultimate in approach aids.

Cambridge

We are of the opinion that whilst the accuracy of ILS is much greater than that of PAR because it is pilot interpreted, capable of quicker interpretation by pilots on the approach, PAR has a great advantage that it is being operated by persons who are not physically controlling the aircraft.

The problems of pilot fatigue causing wrong frequency selection, instrument misinterpretation, and unawareness of the onset of a potential dangerous situation, make an independent monitoring system a valuable back-up.

Ground ILS systems are rarely fully duplicated and PAR does provide an alternative landing aid.

As operators of a non-State airport however, my company would view with alarm a statutory requirement to provide a PAR back-up for an ILS system we may install in the future, purely on the basis of the prohibitory cost.

Coventry

PAR monitoring of ILS approaches from safety aspect is desirable. Airborne and ground equipment failure during an approach could be observed by the radar controller who could take over and apply corrections to continue the approach. The result of a bad approach due to incorrect altimeter setting, a fault which is sometimes made, could be observed and pilots advised during let down approach procedure.

Local flying aircraft during marginal alternating weather not complying with IFR could conflict with an ILS approach and the PAR coverage could indicate risk of collision. Where an ILS pattern is included within a control zone it is possible for an aircraft to commence its approach outside the normal pattern. PAR coverage could instruct and advise the pilot carrying out a normal approach of the conflicting aircraft.

East Midlands

There is little doubt that ILS approaches monitored by PAR increase safety for an aircraft's flight path is monitored in both AZIMUTH and elevation.

It must, however, be remembered that we are only considering the monitoring of approaches in really "sticky" weather and as ILS development is towards the full blind landing system I presume that there is no intention that the actual flare out/roundout should also be monitored by PAR as to the best of my knowledge this would be impossible. It could, therefore, be said that if it is impossible to monitor the most critical stage of a Category IIIC approach (full blind landing) it seems pointless to worry unduly about monitoring other ILS approaches.

We must also take into account the cost of acquiring and maintaining PAR equipment to say nothing of the additional Air Traffic Control staff to man it. Costs would be high for a piece of equipment which presumably would only be brought into use at those few times of the year when the weather is really foul.

If the inquiry's findings should be that "there is a need to provide PAR to monitor, as a means of reducing the risk of accidents the flight paths of aircraft making ILS approaches" then the question must be — at which airports? And if only at the major airports like London Airport — why? For surely such additional costs could only be borne by those airports where money is no object which would raise the question — why should the passenger at LAP be entitled to a safer approach than at any other airport.

Summarizing, PAR monitoring of ILS approaches will undoubtedly increase the safety factor but I do feel that this idea is an unpractical one at most airports, where money could be better spent on:

(a) Further improvements in ground and airborne ILS equipment;

(b) Ironing out the problems arising from the multitude of different weather and operating minima throughout the world. I incline to the view also that in this country, airports should QGO* due weather, the limits being determined by the type of equipment available and in use at the airport.

* = Landing is prohibited at ——————

Exeter

As you will appreciate at Exeter we are not as yet fortunate enough to have ILS or Precision Approach Radar and we therefore feel that we cannot add any constructive comments to your Inquiry.

Glamorgan (Rhoose)

At Glamorgan (Rhoose) Airport, there is surveillance radar (as yet, not fully operational) and Decca 424. It is expected that ILS will be installed in 1971. It is considered that this is an adequate scheme of radio navigational aids for the airport.

Viewed generally, it is considered that the withdrawal of PAR is quite justifiable in national context, subject to the availability of a reliable ILS and the strict observance and enforcement of approved "critical height/runway visual range limits" not only by United Kingdom but also by foreign pilots.

Gloucester and Cheltenham

You will be aware that Staverton has no ILS equipment, therefore any comments are not as a result of practical experience at *this* airport but rather the experience and background over a considerable number of years of the SATCO and control staff.

In their opinion the presence of Precision Approach Radar as a means of monitoring ILS is of great importance for several reasons which are in brief as follows:

(a) Guards against human error (ie misreading of ILS instruments, etc).

(b) Should eliminate possibility of two aircraft colliding through overtaking on approach whilst using ILS.

(c) Creates confidence in pilot's mind by realization that any faults will be quickly indicated through monitor.

(d) Give satisfactory alternate at all stages of approach should ILS equipment fail.

It is realized that economic factors are against the maintaining of such an expensive monitoring system to a general standard and probably could not be accepted at any but the most important airports, but better those than none at all.

Leeds and Bradford

The Instrument Landing System at the airport is not yet operating and there is no Precision Approach Radar equipment at the airport.

In the circumstances, I do not feel able to make any authoritative comment on the contents of your letter.

Liverpool

Prior to the development of Instrument Landing Systems, PAR provided an essential service for aircraft having no airborne equipment enabling them to carry out safe approaches in periods of low cloud, or low visibility.

Following the introduction of ILS, PAR became of secondary importance and its value was largely reduced to monitoring ILS approaches or assisting the relatively few aircraft which were not equipped for ILS approaches.

The continuing improvement in the quality of ILS equipment both on the ground and in the air has further reduced the need for any monitoring of ILS approaches, and this process will continue in the future.

ILS installations at international airports must conform with the specifications contained in Annex 10 and the design of the monitors and the maintenance procedures adopted must preclude the possibility of any erroneous signal remaining undetected. Any failure of the ground or airborne equipment would show on the aircraft instruments, and the crew would take overshoot action.

There is no information that a PAR controller passes to a pilot which he cannot determine himself from the aircraft instruments except perhaps if a pilot has mis-set his altimeter, and whilst flying dangerously low, PAR could in this instance detect the low flight path and advise the pilot.

The monitoring of ILS approaches by PAR would add to the workload of Air Traffic Control without reducing the risk of accidents on normal ILS approaches.

Without taking into account the capital cost of PAR, the annual cost of supplying and maintaining the service would be in the region of £20,000 to £25,000 at each airfield and the value of the service would not in my opinion justify the cost.

Luton

It is considered that the monitoring of Instrument Landing System by Precision Approach Radar is desirable although it would not necessarily assist the pilot on the approach at the critical stage because, at that time, the pilot will either have established himself on the glide path or have had an indication of Instrument Landing System failure. In the latter case the pilot would have started to overshoot or, at worst, will have the aircraft in such a position of flight that neither radar or Instrument Landing System information would enable him to retrieve the situation.

Lydd

I think the general opinion would be that there is at certain aerodromes the need for a PAR system. Possibly a serious accident could have been avoided on a previous occasion at a major airport in this country had the PAR system been left *in situ.*

There is no doubt that PAR provides an added safeguard reducing the risk of undershoots. The only argument against it is, its high cost of installation and operating at small aerodromes where the movement rate is low.

Lympne

A fully qualified professional pilot of any nationality should be capable of executing an ILS approach safely within the limitations accepted for a safe approach. Here we have a human factor which is translating visual signals to physical reactions and with the modern sophisticated instrument presentation of flight systems in the first and second stage jets this translation of visual signals to physical reactions has been accepted as the ultimate to safe and simple operations within the human pilot capabilities. Automation in the approach phase still relies on visual signals, interpreted by the pilot who ensures that his automation is doing the job for which it was so designed.

So far, so good. At this juncture one must consider the correlated safety factor at this most critical stage of the flight, utilizing ILS alone. Let us consider the human factor. Tiredness — work load — turbulent conditions, impinge on safety. Equipment being utilized adds to this factor. Not all aircraft are fitted with modern flight systems. For example our HS 748's are equipped with the somewhat dated ILS needle presentation as are many other types of aircraft. Errors of judgement begin to creep in and flight patterns in the glide slope and localizer concept can become irregular. Critical height can be reached when below the glide slope and in very marginal conditions, as has been proved, other national carriers continue the approach with disastrous results.

Now let us consider the PAR concept. Here we have translation of instructions from the voice to the pilot's ear to conclude the necessary physical reactions. It can be argued that the same principle applies as in the ILS case, visual to physical — aural to physical, but the significant difference is that the eye will sometimes accept signals demanding physical reactions and continue to accept signals without producing the desired effect. The brain, through the medium of hearing, will accept more readily instructions concluding in the necessary physical reactions but if the necessary physical actions are not seen by PAR to be effected, then aural instructions are implemented. This must be accepted as a predominant safety element together with the fact that if a PAR observer detects an unsafe aspect, aural instructions are repeated to avoid further penetration into the unsafe zone. A pilot has grown up with and been educated to obey aural instructions from Air Traffic Control all his life in every aspect of a flight and the human brain involved will more readily accept and act upon aural instructions in preference to restricted visual instructions presented by instrumentation used perhaps in 40 per cent of his approach and landings.

The electronic failure factor of instrument presentation in the aircraft is probably insignificant but it exists and the failure of the ILS system itself is also practically insignificant but it exists and therefore safety is involved.

It may be argued that the voice communication of PAR suffers under the same disadvantage.

Therefore, it is logical to conclude that *both* systems are imperative and the best way to achieve safety is to combine the two systems.

ILS approaches should be made monitored by PAR. The pilots must have the ability to place ILS on voice, knowing that if an unsafe approach is apparent, PAR *voice* will automatically be heard instructing the pilot to correct, and will continue to instruct and repeat until the unsafe becomes safe either by correction of glide slope or localizer and in the latter stages by overshoot.

Finally, until speed control is mandatory and effectively controlled, PAR is essential to maintain horizontal separation in the final stages. Many times a worrying situation can develop by having varying speed aircraft on final approach phases in spite of Air Traffic Control endeavouring to control this factor.

Manchester

I think our feelings on the subject of the retention of PAR are shared by many of our colleagues at the more important United Kingdom airports, many of which are involved in programmes for the early introduction into service of Category II operations. In our opinion, any airport which intends to develop its landing aids and other associated facilities to Category II standard and ultimately Category III, should have the facility of monitoring as much of the approach as possible by means of PAR for a period of 2 or 3 years after the introduction of low minima operations. It is generally considered that the most critical part of a bad weather approach is at the stage at, or shortly before, the point where the decision height is reached. However, statistics will show that whenever bad weather approaches have been broken off at low altitude, this is very often due to the fact that the aircraft had not been firmly established on the ILS centreline or glide path at a much earlier stage. We feel that the use of PAR monitoring for Category II operations when first introduced will enable controllers to give the pilot early warning that all is not well. Psychologically the benefits to both the pilot and, incidentally, to local residents, are considerable.

Our second main reason for the retention of PAR at Manchester Airport is as a standby when the ILS is out of service. As you know, the Board of Trade have been modifying certain ILS installations, including our own, to up-grade the equipment to provide a Category II facility. This work has meant that the glide path in particular has had to be taken out of service for protracted periods, and without the back-up facility of PAR we should have lost a lot of traffic over the last few months. As this development work is likely to continue spasmodically over the next 2 to 3 years when a comparable programme of development is initiated for the 06 landing direction, we may expect similar periods during which either or both elements of the ILS will be out of service. Retention of the PAR is therefore essential.

Newcastle

It is difficult to say whether the monitoring of an approach will have any bearing upon the risk of accidents. When there is a malfunction of the ILS during the stage of an approach, this is immediately indicated to the aircraft captain on his instruments and he should take appropriate action without being told from the ground. The only time that PAR or some form of monitoring would be instrumental in avoiding an incident would be when, due to physical or geographical reasons, either the localizer or glide path beam is bent and this, of course, would not be indicated to the pilot on his instruments. If, for any other reason, an aircraft gets into difficulties during an approach, the fact that a controller is monitoring the flight path will make very little difference to subsequent events in the majority of cases. With PAR, it will obviously indicate to the controller what happened, but it is doubtful whether his advice to the captain would be of any use.

Plymouth

With regard to your terms of reference, as an ex-BUA pilot I would personally wish to state that there is a need for the provision of Precision Approach Radar (PAR) to monitor the flight paths of aircraft on ILS approach.

Portsmouth

Portsmouth City Airport has none of the equipment referred to in your letter and we are therefore unable to give you any practical help with this Inquiry.

Shoreham

We are prepared to assist you in any way possible. Although the airport has no ILS the Company has a Chief Test Pilot and experienced pilots who should be able to contribute to the Inquiry.

Southampton

Unfortunately we do not have at this airport PAR, radar and/or an ILS system installed.

We would very much like both these facilities, but cannot afford to install them.

Southend-on-Sea

No ILS is installed, although formal application for a frequency allocation has been made, nor is PAR in use.

However, Southend is fortunate in having two separate radar systems:

(1) a Cossor 787 Surveillance Radar providing surveillance radar approaches terminating at 2 nautical miles from touchdown and

(2) an Ekco Airfield Radar Approach Aid providing radar approaches terminating at ½ nautical mile from touchdown. If and when ILS is installed the ARAA could be retained for monitoring purposes.

From discussions with organizations operating ILS and PAR, it appears that the reliability and serviceability of ILS is greater than that of PAR. Surely, if the performance of the ILS is below the normal standard for a particular installation, the fact is notified and higher landing criteria apply.

The Airport Commandant is not convinced that any advantage accruing from the installation of PAR in addition to ILS would be sufficient to offset the considerable capital outlay, together with operating costs, including staff. Nevertheless, if PAR is already *in situ*, there may be a case for its retention.

Swansea

Swansea Airport does not have ILS, and therefore one cannot comment on the reliability of that equipment experienced at Swansea Airport.

It is perhaps pertinent to observe that the Inquiry has to my knowledge been set up as a result of an aircraft accident occurring at Gatwick Airport, following an ILS approach after Precision Approach Radar had been withdrawn from that airport. Had PAR been available to the captain for Air Traffic Control to monitor his approach, he would have been advised that he was below the glide path, and there is every possibility that the accident would have been avoided. On the other hand, the ILS ground equipment and the ILS receivers in the aircraft are subject to rigid maintenance and fail-safe requirements, and possibly the accident at Gatwick, and other airports which may have occurred, were not as a result of any shortcomings in the Instrument Landing System, either in the ground or aircraft equipment, but in the interpretation of altimeter indications or settings.

Briefly, I would say that if the Inquiry satisfies the Assessors that there is a risk of accident as a result of a possibility of a fundamental deficiency in the ILS ground or aircraft equipment, then it is certainly desirable that PAR be provided for Air Traffic Control to monitor all ILS approaches. If the Assessors are satisfied that there is no possibility of a fundamental deficiency in the ILS ground or aircraft equipment, then I would suggest that their approach to this problem should be directed towards providing an automatic means of indication to the pilot, additional to his glide slope indicator, that he is below the desired glide path. Perhaps this could be achieved electronically, as an additional audible/visual indication of the required height when passing over each of the outer, middle and inner ILS marker beacons.

Tees-side

The Airport Committee considers that Precision Approach Radar as an adjunct to the Instrument Approach System (ILS) like so many other pieces of equipment could perform a very useful function but, if ILS was used in accordance with its prescribed procedure PAR would be a very expensive luxury. Tees-side Airport has been responsible for drawing attention to the need for strict observance of weather minima (related to Runway Visual Range) and, if this was observed, then a standard ILS approach should be an acceptably safe procedure.

The argument in favour of PAR would appear to stem from accidents which have arisen when captains of aircraft have elected to attempt an approach in marginal conditions and in spite of Air Traffic Control advice as to the current RVR for the runway in use.

It is, of course, for consideration, whether existing RVR limitations are sufficiently realistic having regard to the known fallibilities of the system and (as Tees-side has several times tried to make clear) whether in the case of aircraft of other than British registration the system, particularly to operators from tropical countries, is sufficiently safe to be applied on the same basis as that applicable to British aircraft.

APPENDIX 7

Opinions of foreign countries

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Letter from: *International Civil Aviation Organization*
dated 19 November 1969 Ref 13/9.3

Subject: *Views on the use of precision approach radar*

Dear Sir,

. . . please find below our comments and, in the attachments, the summary of views recently collected from States in the European Mediterranean Region on this subject.

2 First of all I should mention that, from a technical point of view, Precision Approach Radar equipment is considered as one of the standard radio aids of navigation since technical specifications for this equipment are included in Annex 10, Volume 1.

3 In addition, a number of regional meetings have made specific recommendations as to the locations where this type of equipment should be provided and requirements for such equipment were subsequently included in the appropriate Regional Plans of ICAO. (They are generally listed in "Table COM3 — Radio Navigation Aids" in the air navigation plans for the various regions).

4 Since a number of years it has been noted that opinions on the usefulness of this type of equipment are divided, especially in view of the fact that PAR equipment is rather costly as regards initial installation, continued maintenance of equipment and maintenance of proficiency of the operating personnel. In addition, it does not permit a lowering of the minima for the conduct of instrument approaches. It is therefore felt that it might be more useful if States were to concentrate on installation and maintenance of ILS installations rather than split their efforts between them and PAR facilities. However, as there is also the question of military interests involved, particularly in Europe, the ultimate position taken by States in this matter is very much influenced by local conditions. (The two letters attached, which have been circulated by this Office and which are believed to be self-explanatory, illustrate this point.)

5 With respect to the attached letter of 12 May 1969, I am also sending you a photocopy of the position taken by IFALPA, which was received after the completion of our summary.

I hope that the above and the attached material will be of assistance to you.

Yours faithfully

H MARZUSCH
ICAO Representative
European Office

Letter from: *International Federation of Air Line Pilots Associations*
dated 28 August 1969

Subject: *Withdrawal of PAR in Europe*

Dear Mr Marzusch,

In reply to your letter Ref: T 13/9.3–774, dated 12 May 1969, the Federation has now given consideration to the proposals to withdraw PAR in Europe. In IFALPA's view, however, this facility provides an essential component to air safety in the circumstances outlined below and we would therefore urgently request that the facility be retained in the location described:

(a) at high density traffic aerodromes;

(b) where parallel runways are in simultaneous use (eg London and Frankfurt);

(c) where the ILS beam is known to suffer regularly from instability (eg Genoa due terrain effects).

It is believed that these requirements are self-explanatory but if it is thought desirable, our representatives will be pleased to give further background to the IFALPA position either at the forthcoming Limited EUM Meeting or in any manner convenient to you.

Yours sincerely

C C JACKSON
Executive Secretary

Letter from: *International Civil Aviation Organization*
dated 12 May 1969 Ref T 13/9.3–774

Subject: *Withdrawal of PAR facilities from international aerodromes*

Sir,

I have the honour to refer to my letter, reference T 13/9.3–1993 of 26 November 1968, relating to the withdrawal of PAR facilities from international aerodromes.

As this question has recently received particular attention in a number of States, I am sending you herewith excerpts from the replies received from States and Organizations on this subject (Appendix A refers).

From these replies it would appear that two basic considerations regarding the use of PAR facilities have emerged:

(i) the military services continue to consider PAR as a rather important part of their navigation services provided for approach and landing purposes and, as a consequence, PAR facilities operated by the military at jointly used aerodromes will be retained;

(ii) in all other cases where purely civil considerations prevail, the decision regarding retention or withdrawal of PAR facilities must be based primarily on local factors which vary considerably from location to location. Agreement on a generally acceptable policy which can be applied rigidly within the entire Region appears, therefore, very difficult to obtain.

It is also apparent from the replies that economic considerations play an important role in the question of PAR facilities. This concerns not only the initial installation costs but also the recurring expenses required for the maintenance of the equipment and the personnel costs involved.

Although no generally applicable principles can be retained regarding the use of PAR, it is the consensus of States and operators that the ILS remains the primary landing aid at international aerodromes and it would therefore appear that in all those cases where the decision to maintain or install a PAR is likely to adversely affect the performance of the ILS, be it due to dispersal of funds or manpower, priority should definitely be given to ensuring the highest possible standard of operation of the ILS concerned.

Accept, Sir, the assurances of my highest consideration.

H MARZUSCH
ICAO Representative
European Office

APPENDIX A to letter from ICAO of 12 May 1969

Excerpts from replies to State letter T 13/9.3–1993 of 26 November 1968 on the subject of withdrawal of PAR facilities from international aerodromes

I States located geographically in the EUM region

Austria

Due to experience in the last years we do neither intend to establish additional PAR facilities nor to withdraw existing facilities at Wien Airport, particularly because of situations in which aircraft have already received valuable assistance. Therefore, amendments to the Regional Plan are not envisaged.

Belgium

The Belgian Administration is contemplating withdrawing the PAR facilities at Brussels National airport on 1 November 1969.

Users have already been requested to comment on the utility of those facilities, and the approach control services at Brussels National have been asked to establish PAR utilization statistics.

As soon as the Belgian Administration has this information available it will let you know its final decision.

Finland

For use at Finnish aerodromes there are PAR facilities available at Jyvaskyla, Kuopio, Pori and Rovaniemi aerodromes.

They are military-owned equipment which are made also available to civil air traffic, warranted by an agreement between the Finnish Air Force and the Department of Civil Aviation.

ILS equipment is available as a primary aid at the aerodromes in question. PAR is mainly used for military traffic and therefore the Finnish Air Force have no intention of withdrawing the PAR facilities mentioned within the near future.

France

I have the honour to inform you that, although the French Administration is in favour of restricting the number of facilities, it is not at present in a position to accept the suppression of such aids for its territory in the Regional Plan.

The existing aids at French aerodromes listed in Table AGA 1 (Bordeaux, Le Bourget, Strasbourg, Orly and Tours) are still of use and require the continued assignment of specific VHF frequencies.

Moreover, experience shows that special topographical or environmental conditions may justify the joint use of ILS and PAR on the same QFU (as in the case of Berlin–Tempelhof for example). In other cases where the topography makes it difficult to install an ILS with sufficient guarantees as to its functioning and where, moreover, the meteorological conditions do not justify the establishment of very low landing minima, it is permissible to think it more worth-while to advocate the installation of a PAR.

Under these circumstances, the French Administration considers that any decision to be taken in this field, either to withdraw a facility or to install a new one, cannot be based on a general principle but on a detailed study of each problem raised, in consultation with the airlines.

F R Germany

When reading your letter I have noted that you misinterpreted my suggestion made in connection with your enquiry in my reference letter of 5 November 1968 (reference 2). In this letter, I have not referred to the withdrawal of PAR facilities, but to a limitation in the provision of PAR facilities at international aerodromes in the Federal Republic.

As to the question of operating PAR facilities, I am in principle in agreement with the viewpoint given in paragraph 3.1.4.10 of the report of the Fifth EUM RAN Meeting. I am, however, of the opinion that at the present time the reduction of weather minima for approach flights on international aerodromes by means of PAR are of secondary importance only. To my mind the following points are of primary importance:

traffic structure and composition,

joint military use,

supervision of approach flights with a view to noise disturbances,

regularity of the airport with regard to outages of instrument landing systems

monitoring and assisting pilots during precision approach or instrument approach in unfavourable meteorological conditions, and last but not least

general viewpoints for the provision of aerodromes with PAR facilities respectively their retention on the individual international aerodromes.

These points supporting the retention of PAR facilities have also been confirmed by the users of these facilities.

Present plans envisage that the international aerodromes at Düsseldorf, Hamburg, Hannover, Köln–Bonn, München, and Stuttgart will receive a PAR facility each, whereas Frankfurt will be fitted with two PAR facilities. The majority of these facilities are already in operation at the aerodromes mentioned. The remaining will be put into operation in the near future.

Contrary to the EUM Regional Plan the Bremen and Nürnberg airports will for the time being not be equipped with PAR.

The valid EUM Regional Plan should be amended according to the above information.

Greece

We have the honour to inform you as follows:

(1) No PAR facilities exist at the Hellenic civil aerodromes.

(2) Requirements for such facilities, as shown in the Regional Plan concern Andravida and Elefsis aerodromes, which are military aerodromes, available also to civil aircraft as alternate.

(3) According to the views expressed by the RHAF the said facilities, being very useful for the safety of flights, should be retained.

(4) Therefore, apart from Elefsis aerodrome, where a PAR facility already exists, another one is to be installed at Andravida aerodrome.

Ireland

We do not at present contemplate the withdrawal of these facilities from Shannon or Dublin Airports. The PAR equipment in use at these airports is of modern design and can be expected to be of effective use for some years ahead. Experience has shown that extensive use of PAR facilities is made here particularly at Dublin Airport where, under certain weather conditions, PAR is used almost exclusively as the landing aid.

The EUM Plan is incorrect in showing PAR as operational at Cork. An operational requirement for PAR exists at Cork and will be met by the installation of a Quadradar in 1969.

Morocco

I have the honour to forward to you the Moroccan Administration's point of view on the withdrawal of PAR facilities at international aerodromes in the EUM Region.

Our national airline has been consulted as a user of the international aerodromes served by its aircraft at which precision approach radar is available, and considers it necessary to maintain those facilities. Although PAR is now of less interest in view of the widespread use of ILS, it nevertheless offers a means of control which is particularly appreciated by flight crews in cases of breakthrough at operational minima.

Its suppression would entail a reduction in the safety facilities which may seem to be superfluous under normal conditions but which are of prime importance in case of difficulty or equipment failure.

Nevertheless, it is pointed out that, as far as Moroccan aerodromes are concerned, the traffic density and topographical and meteorological conditions do not justify the installation of Precision Approach Radar.

However, the users consider that the PAR facilities already existing at international aerodromes should be maintained as flight safety should take priority over all other considerations.

Netherlands

With regard to your question about our experiences since the withdrawal of the PAR at Schiphol Airport, I inform you that no need is felt to maintain the facility, neither by the pilots who call at Schiphol regularly, nor from the point of view of improvement of the operational performance of the service.

Our national carrier KLM is also of the opinion that no PAR facilities are needed where ILS is available.

Norway

For use at Norwegian international aerodromes there are PAR facilities available at Oslo/Gardermoen and Stavanger/Sola.

As you may have noticed from KfL serial A, No A/1/1960, it is military owned GCA equipment which is made available to civil air traffic, warranted by an agreement between the Royal Norwegian Air Force and the Directorate of Civil Aviation.

In addition to the PAR facilities, ILS equipment is also available at the aerodromes in question. It therefore follows that for international civil air traffic, the PAR facilities are mostly being used for monitoring of ILS or ADF approaches, whereas for the military traffic — especially for jet fighters — there is still a definite requirement for a continuation of PAR as a primary aid at these aerodromes.

I have, therefore, no intention of withdrawing the PAR facilities mentioned within the near future.

Portugal

I have the honour to inform you that the Portuguese administration does not intend to install PAR equipment at the international civil aerodromes under its responsibility.

Spain

Concerning plans of States in the EUM Region for the installation of new PAR facilities and maintenance of existing ones at international airports, I have to inform you that this administration has made no plans for the installation of the systems which were indicated in the Regional Plan for the airports of Madrid and Barcelona (a corresponding amendment should be made to Appendix B showing that Madrid airport is not equipped with PAR and that there are no plans to install PAR at Barcelona).

This administration is in agreement with the proposal of the F R of Germany not to consider PAR facilities mandatory at international airports.

Sweden

As to PAR facilities at the international aerodromes in Sweden our policy is as follows.

When reliable ILS facilities are available for the relevant landing runways the PAR will be withdrawn.

At Stockholm/Arlanda the PAR will be closed for continuous operation in the near future. However, until further notice the PAR may be used on request for military operations and as a stand-by for the ILS facilities when they are shut down for maintenance during a long period of time.

The PAR facilities at Stockholm/Bromma and Göteborg/Torslanda will be maintained in operation as long as there is ILS in one direction only at these aerodromes.

According to information received from SAS no inconveniences have been experienced owing to the withdrawal of PAR.

We have noted the last paragraph of your above letter and find it satisfactory that the established procedure for the amendment of ICAO Plans be followed in this case too.

In due time we will submit to you a proposal for amendment as regards withdrawal of PAR facilities in Sweden now included in the plan.

Switzerland

During periods of interruption of the ILS (eg maintenance, reconstruction, etc) PARs still remain a very valuable means. The supervision of ILS approaches is often much appreciated by pilots.

On the other hand, the maintaining of training possibilities for PAR controllers becomes a problem more and more important and the costs of maintenance in relation to the operational use are extremely high. Therefore Switzerland

> will not consider the procurement of new PAR equipment;
>
> will probably discontinue to provide PAR services as soon as our main airports will be equipped with two precision approach runways with ILS (after 1972 approx);
>
> in the meantime will have to reduce controller training requirements from now fifty movements to about twenty-five movements per year.

United Kingdom

Consultations on the subject of the letter are taking place at Director level, and it is hoped to have an answer with you by the end of this month.

II States located outside the region but having international civil aviation interests therein

Australia

It is advised that Australia has no objections to the proposal to withdraw PAR facilities from international aerodromes within the EUM Region.

Colombia

The Colombian Department of Civil Aviation is planning no further PAR facilities and the only one to be kept is that at Eldorado Airport for surveillance and ILS approaches as well as for the purpose of training air traffic control personnel and flight crew members.

The foregoing is based particularly on the fact that the efficiency of modern ILS equipment takes away a great deal of the usefulness from the PAR facilities which, as you know, are not authorized as primary approach aids except in emergencies and then only in association with other types of facility.

It is also to be noted that the international airports in Colombia are not subject to conditions of low visibility such that PAR-assisted surveillance of ILS approaches is indispensable.

Ethiopia

Please note that the opinion of our National Airlines on the proposed withdrawal of the PAR facilities within the Republic of Germany is quoted as follows: "The present facility would certainly be ideal for non-routine operations. Our present operation depends mostly on fixed aids for navigation and instrument approaches. With the event of lowering Ethiopian's minimums, it would be desirable to have approaches monitored."

India

India has stated that she has no objection provided that other adequate and reliable landing aids are available for use by large turbo-jet aircraft.

USA

My Government has been studying user demand for PAR service at civil airports for several years. The studies revealed that there is very little use of PAR by civil aviation. As a result, fourteen PAR installations were decommissioned during 1968. A six-month survey of eight other locations is being evaluated and analyzed. This analysis, when considered along with other operational factors, may result in additional PARs being decommissioned.

The most recent study which was completed during 1968 indicated that no operational disadvantage was apparent at those locations where PAR service had been discontinued. In this regard, PAR service has not been included in any major United States ATC terminal facility modernization programs.

III International organizations

IATA

The subject of withdrawal of PAR facilities was considered by the recent Eleventh Meeting of the IATA

EUM & MID Technical Panel and the airlines present felt that it was not possible to take a decision on a regional basis on the general withdrawal of PAR. Each case will be considered on its merits and among the factors being taken into account are the following:

(i) The effectiveness of the ILS equipment.

(ii) The reliability of the ILS installation, including the availability of a stand-by installation.

(iii) The possibility that PAR may be required for monitoring operations on parallel runways.

We hope that the above comments may be included in your résumé of the situation.

APPENDIX A to letter from ICAO of 12 May 1969

Addendum

II States located outside the region but having international civil aviation interests therein

Brazil

On the basis of information supplied by the Brazilian airline VARIG, which flies regularly to the EUM Region, I am able to inform you that the proposal to delete PAR facilities from the Regional Plan could, in our view, be carried out without any major operational disadvantages.

The Brazilian Directorate considers that with the existence of ILS as a main aid to approach and landing, and insofar as such aids are in perfect working order, there is no reason to invest a very large amount of capital in installing and maintaining PAR equipment for the sole purpose of monitoring ILS approaches.

The above being the opinion of the Directorate of Airways, any proposal made on those lines will go unopposed by the Brazilian Government.

Venezuela

The Venezuelan Administration is in no way surprised at the proposal to do away with PAR facilities at international aerodromes. This was to be expected, not only because of the high cost of installing, operating and maintaining such aids, as pointed out in the report, but also for such technical and operational reasons as the obvious fact of the improvement of PPI aerodrome radar, which has made great accuracy possible in approaches monitored by this means, with increasingly lower limits, taken together with the fact that this type of radar can serve a number of runways on the same aerodrome without the well-known restrictions suffered by PAR in this respect.

Another factor felt to have been decisive in establishing the new viewpoint is the progress also made in the different categories of ILS approach facilities, which has given pilots greater confidence and increased safety in using it.

To sum up, it may be said that combined use of both these facilities — PPI and ILS — has decisively influenced the issue of the progressive elimination of PAR facilities, and that this trend can only be strengthened as further improvements are made to these aids.

Italy

This Administration is of the opinion that it should be desirable to maintain those PAR facilities which are already in operation, even if commercial aviation is using them to a small extent, also in view of the considerable development in the field of Category II operations.

As to the policy to be followed it is thought that:

> Any possible closing of PAR facilities should be subject to consideration of the availability and reliability of the other radio aids approach and landing now in operation at each of the aerodromes, as well as of the orographic features of the area surrounding them.
>
> As it is impossible to state general principles because of the different conditions existing at each location, it is thought that at least the following factors should be taken into consideration to see whether it would be useful or not to close PAR facilities:
>
> (a) reliability of ILS facility(ies) in operation at the aerodrome (ILS facilities on at least two runways would be desirable);
>
> (b) availability of a standby ILS transmitter to be quickly and automatically operated in case of a failure in the working transmitter;

(c) particular orographic features of the area surrounding the aerodrome;

(d) specific requirements for the provision of such equipment to control procedures for simultaneous approaches to parallel runways.

The installation of new PAR facilities cannot be excluded a priori. However, it should be restricted to those really extraordinary circumstances as justified by particular environment and operational condition (see (a), (b), (c), (d), and (e) above).

It is pointed out that the foregoing takes into account also the Italian flag air carrier's view, as requested (cf. para 2 of referenced letter).

Letter from: *International Civil Aviation Organization*
dated 26 November 1968 Ref T 13/9.3–1993

Subject: *Withdrawal of PAR facilities from international aerodromes*

Sir,

I have the honour to inform you that the Federal Republic of Germany has raised the question of withdrawal of PAR facilities from international aerodromes and has expressed its desire that this matter be brought to the attention of EUM States in order to obtain their views on this question.

You will recall that, at the EUM V RAN meeting, held in February 1966, it was agreed that normally only those PAR facilities should be included in the Plan which were already in operation since it was felt that, because of the high installation and current costs of such equipment, it was not the best possible investment in order to improve the reliability of operations at aerodromes. (For your convenience, the relevant part of the Report of the EUM V RAN meeting is reproduced in *Appendix A*.)

As a consequence forty-eight PAR facilities were included in the EUM Regional Plan of Radio Navigation Aids of which eight were not implemented at the time. In the meantime three proposals for amendment by the Netherlands (EUM/33–COM/29), Denmark (EUM/36–COM/32) and the United Kingdom (EUM/93–COM/70) have reduced this number to forty-three PAR facilities of which four are not yet implemented. Details on the present situation are given in *Appendix B*.

Studies on this subject, conducted by a number of States, seem to indicate that decisions regarding the future disposition (or the new installation) of such facilities cannot exclusively be based on movement figures of the aerodrome concerned. In fact, in many cases, the composition of the air traffic and more particularly requirements resulting from the frequent use of the aerodrome by military aircraft, specific local topographical and/or meteorological conditions and technical considerations concerning the performance of other approach aids seem to be of much greater significance. It is nevertheless noteworthy that there are still three or four States in the Region which appear to maintain the policy of providing, as a matter of principle, a PAR at each of their international aerodromes and it may therefore be useful to obtain a general view on this subject.

I would therefore be grateful if I could be informed of the plans of those States for whose international aerodromes a requirement for PAR is still shown in the Plan. But it would also be useful to obtain comments from other States and especially those having withdrawn such facilities, especially as regards the latter's experience made since the closing of their facility or facilities. In addition it would be useful to have an indication from the users as to their point of view.

Finally, I should like to point out that, since the facilities shown in Appendix B form an integral part of the EUM Regional Plan any change of their status and especially their withdrawal, should be made the subject of an appropriate proposal for amendment of the Plan prior to effecting such changes.

Accept, Sir, the assurances of my highest consideration.

H MARZUSCH
ICAO Representative
European Office

APPENDIX A to letter from ICAO dated 26 November 1968

Excerpt from the report of the EUM V RAN Meeting concerning GCA
(DOC 8588, EUM/V, page 3–15)

"*GCA*

3.1.4.9 The Committee noted that over the last few years, considerable developments had been taking place regarding the relation of GCA units with Approach Control Offices and Area Control Centres. In many cases, the GCA unit was no longer provided with its own surveillance radar element, but utilized information derived from terminal area radars which are also used by approach control and departure control positions of ACCs.

3.1.4.10 Furthermore, while GCA was a valuable aid to monitor ILS approaches by aircraft, its provision was not considered adequate to permit a reduction in the weather minima. In view of this situation, no additional requirements for the provision of this installation were put forward. In fact, it was pointed out that, because of its high initial installation cost and the considerable current expenses required for the continued operation of such a facility, it may not be the best possible investment in order to improve reliability of operation at a particular aerodrome.

3.1.4.11 In view of this situation, it was agreed that only already existing installations should be shown in the Plan of radio navigation aids and that reference should only be made to the PAR element of the installation."

APPENDIX B to letter from ICAO dated 26 November 1968

Extract from the EUM Regional Plan concerning the requirement for PAR facilities at international aerodromes
Extrait du plan régional EUM relatif aux installations PAR nécessaires aux aérodromes internationaux

Legend/Légende: Operating/en service X Planned/Prévu O

Station	*PAR*	*Status/Statut*
Austria/Autriche		
WIEN/Schwechat	1	X
Belgium/Belgique		
BRUXELLES/National	1	X
Bulgaria/Bulgarie		
BOURGAS/Sarafovo	1	O
SOFIA/Vrajdebna	1	X
VARNA/Acsakovo	1	X
Czechoslovakia/Tchecoslovaquie		
BRATISLAVA/Ivanka	1	X
BRNO/Turany	1	X
PRAHA/Ruzyne	1	X
France		
PARIS/Le Bourget	1	X
PARIS/Orly	1	X
Germany/Allemagne (Berlin)		
BERLIN/Tempelhof	1	X
Germany (Fed Rep)/Allemagne (Rép Féd)		
BREMEN/Bremen	1	X
FRANKFURT MAIN/Frankfurt Main	1	X
HAMBURG/Hamburg	1	X
HANNOVER/Hannover	1	X
KÖLN/Köln–Bonn	1	X
MUNCHEN/München	1	X
NURNBERG/Nürnberg	1	O
STUTTGART/Stuttgart	1	X
Greece/Grece		
ANDRAVIDA	1	O
ATHINAI/Elefsis	1	X
Hungary/Hongrie		
BUDAPEST/Ferihegy	1	X

Station	*PAR*	*Status/Statut*
Ireland/Irlande		
CORK/Cork	1	X
DUBLIN/Dublin	1	X
SHANNON/Shannon	1	X
Italy/Italie		
MILANO/Malpensa	1	X
NAPOLI/Capodichino (Pomigliano)	1	X
ROMA/Ciampino	1	X
ROMA/Fiumicino	1	X
TORINO/Caselle	1	X
Norway/Norvege		
OSLO/Gardermoen	1	X
STAVANGER/Sola	1	X
Poland/Pologne		
KRAKOW/Balice	1	X
WARSZAWA/Okecie	1	X
Spain/Espagne		
BARCELONA/Barcelona	1	O
MADRID/Barajas	1	X
Sweden/Suede		
STOCKHOLM/Arlanda	1	X
STOCKHOLM/Bromma	1	X
Switzerland/Suisse		
GENEVE/Cointrin	1	X
ZURICH/Zürich	1	X
United Kingdom/Royaume-Uni		
LONDON/Heathrow	1	X
MANCHESTER/Manchester	1	X
Yugoslavia/Yougoslavie		
BEOGRAD/Beograd	1	X

Replies to a letter from this Inquiry

Letter from: *French Ministry of Transport, Directorate of Air Navigation*

Subject: *Future use of PAR in France*

Sir,

Following your letter, I have the honour to inform you that France is no longer going to install PAR at her civil aerodromes.

The reliability of this equipment is less than that of modern ILS. The same applies to the precision. The GCA intervention time-lag is very long.

All these factors mean that it is inconceivable, in the present state of technical development of the respective systems, to consider the use of GCA with minima comparable to those used daily with ILS.

We consider that the present mode of operation of ILS has an intrinsic control system in the form of the pilot. This is why our administration's philosophy regarding all-weather landing has always been based on the active intervention of the pilot in this system.

It should be noted that, even under present conditions and for aircraft equipped with automatic landing systems, we have retained a critical height which allows for overshoot in case of last minute difficulties. It would have been possible to take up a different position, but here again this was done deliberately and on the basis of the consideration that the pilot should remain a decisive factor in operation with reduced minima.

In any event, our administration will keep a GCA at Le Bourget in order to meet any contingency. Runway 25 at Orly, on the other hand, will also be equipped with ILS which will mean that the two East/West runways at this aerodrome will be equipped in both directions. The PAR will subsequently be withdrawn from this aerodrome.

We shall be pleased to give you any further information you require.

I am, etc

(Signed) LANSALOT BASOU
Ingénieur Général de la Navigation Aérienne
Director of Air Navigation
for the Minister for Transport

Letter from: *Eire Department of Transport and Power, Civil Aviation Division*

Subject: *Future use of PAR in Eire*

I am directed by the Minister for Transport and Power to refer to your letter JQ/112/09 of 2 February 1970 in regard to Precision Approach Radar (PAR) and to provide you with our views on the operational value of this type of equipment.

The view held by us and communicated to ICAO was that we did not at present contemplate the withdrawal of PAR facilities from Irish airports. In fact, since that letter was written (December 1968) a PAR unit has been installed at Cork and is expected to be fully operational early in March 1970.

We now confirm to you our views as already expressed to ICAO and, indeed, our decision to retain PAR facilities was shown to be the correct one as the FAA saw fit to rescind an order which had closed down PAR at eight major airports in the United States in an effort to reduce the number of aircraft accidents occurring during the final approach phase of flight. In this connection you might refer to Interavia Air Letter No 6687 of 4 February 1969.

Apart from the general statement already forwarded to ICAO regarding the retention of PAR at Irish airports the following detailed reasons are submitted for your information:

(1) With existing and foreseen aerodrome layouts in Ireland, Precision Approach facilities using ILS cannot be provided to certain main runways due to installation problems.

(2) *Economic considerations involved.* It will be appreciated that *one* Precision Approach Radar Unit can provide Precision Approach facilities to at least *four* different runways. To replace PAR facilities completely at Irish Airports would mean that *three* additional ILS approach facilities would have to be installed at Dublin and Cork and *two* at Shannon.

(3) It is considered that PAR is an essential requirement for monitoring ILS, VOR and ADF approaches particularly in marginal weather conditions. Furthermore, the very essential requirement to monitor ILS approaches to parallel runways is a most important consideration. Such monitoring results in:

   (a) The more efficient control of the increasingly mixed air traffic now operating at Irish airports.

   (b) Checking the performance standards of operators of varying capability.

(4) PAR can be used as an alternative means of Precision Approach in the event of outage or interruption of the ILS facility.

(5) In some cases PAR is the only usable Precision Approach aid for classes of air traffic not fitted with ILS or having equipment of questionable performance — in such circumstances and in the event of an emergency arising PAR is an invaluable aid.

(6) PAR can be used for the recovery of military aircraft not equipped with ILS in adverse weather conditions in the event of their diversion to civil airports.

(7) PAR has the capability of monitoring flight paths for noise abatement purposes.

Yours faithfully

S COLLINS

Letter from: *West Germany, Federal Ministry of Transport*

Subject: *PAR Operation*

Dear Sir,

In reply to your above mentioned letter, I kindly offer the following comments on the operation of Precision Approach Radar (PAR) in the Federal Republic of Germany (FRG):

In principle I am in agreement with the statement contained in paragraph 3.1.4.10 of the report on the Fifth EUM RAN meeting. In my opinion, however, the use of PAR in order to be able to reduce the weather minima for approaches is only of secondary importance. To my mind the following aspects have a more important bearing on the installation of PARs:

Structure and composition of air traffic;

Joint civil/military use of aerodromes;

Surveillance of approaches with a view to the adherance to prescribed low-noise procedure;

Regularity of air traffic with regard to possible breakdowns of the Instrument Landing System;

Monitoring and assisting pilots during instrument approaches in adverse weather conditions;

General viewpoints for the provision of PAR services respectively their retention at international aerodromes.

These points supporting the retention of PAR have also been confirmed by the users of the facilities.

Taking into consideration the above aspects the FRG operates or will operate PAR facilities at the international aerodromes of Hamburg, Düsseldorf, Hannover, Frankfurt, Köln–Bonn, Stuttgart and München.

I hope that the above information will conveniently serve the Inquiry.

Yours sincerely

On behalf of the Federal Minister of Transport

Letter from: *Netherlands Ministry of Transport*

Subject: *Withdrawal of PAR facilities*

Dear Sir,

With reference to your above-mentioned letter I can inform you that in response to the inquiry by ICAO of 26 November 1968, reference T 13/9.3–1993, on the subject of withdrawal of PAR facilities, we expressed the view that "no need is felt to maintain the facility, neither by the pilots who call at Schiphol regularly, nor from the point of view of improvement of the operational performance of the service" and "Our national carrier KLM is also of the opinion that no PAR facilities are needed where ILS is available".

We still hold the same view and feel that there is no need to provide PAR for a monitor function as meant in your letter.

Yours faithfully

(A A de ROODE)
Director of Telecommunications
and Air Traffic Control

Opinion of the Guild of Air Traffic Control Officers

Extract from the Guild's letter of 1 August 1969

1 The general question of whether or not there is a need for Precision Approach Radar is one about which most controllers hold strong views, either for or against, depending upon the air traffic environment in which they operate. Broadly, these views are influenced by such factors as: the type of aircraft operations, the surrounding terrain, the pilot-interpreted aids available and the capabilities of the pilots concerned.

2 However, the terms of reference of your Inquiry make it plain that you are only to consider the monitoring by Precision Approach Radar (PAR) of the flight paths of aircraft making Instrument Landing System (ILS) approaches, as a means of reducing the risk of accidents. We will therefore endeavour to give our views on the need for PAR in the context of ICAO PANS/RAC (DOC 4444–RAC/501/9). In this document (an extract of which is at Attachment "A"), Radar monitoring is defined as:

> "The use of radar for the purpose of providing aircraft with information and advice relative to significant deviations from nominal flight path."

3 The high potential degree of accuracy of PAR (see Attachment "B") can only be attained through the application of stringent adherence to specified tolerances in site calibration, frequent setting-up checks and overall system flight checks by specially-equipped aircraft. To obtain the highest degree of accuracy required for PAR approaches it is necessary for the controller to have regular practice. When PAR is used for monitoring ILS approaches such regular practice is not essential for him to be able to detect deviations from ILS glide path or nominal track — but of course regular practice is essential if he is required to take over and provide a PAR approach.

4 It is this consideration which divides controllers in their views on PAR, plus the impracticability of obtaining sufficient practice in periods of good weather or at high traffic intensity aerodromes where the landing flow would be seriously disrupted.

5 With the introduction of more accurate ILS ground installations aimed at Category III operations, limits of tolerance have narrowed as system accuracy has increased. It has been found that, because of stricter tolerances, Category II ILS is more subject to "tripping" than Category I — thus it is more frequently rendered unreliable and requires adjustment more often to keep within its narrower tolerance. Furthermore, it is understood that the integrity of the ILS data received by the aircraft may be seriously affected by reflections and other radiations, which produce spurious guidance signals.

6 To overcome these operational deficiencies new equipment, known as correlation-protected instrument landing system (CPILS), is being developed. However, there will inevitably be some delay before its introduction into operational service and in the meantime the deficiencies persist.

7 Having regard to these factors, a case can be stated for the need to use PAR in a monitoring function until these operational deficiencies have been overcome since it is the only system presently available to give an independent check of the aircraft's performance on the ILS flight paths.

8 We have stated the operational advantages of PAR monitoring of ILS approaches in certain circumstances, but must add the reservation that a monitoring function will not necessarily reduce the risk of accidents where aircraft deviate significantly from ILS flight paths in the final stages of approach since the time lapse between controller recognition of the deviation, communication of this information to the pilot and his reaction to the information may be too great to permit recovery of the correct flight path before a disaster occurs.

9 Finally, we have deliberately refrained from discussion of the cost/benefit aspects of the provision of PAR for monitoring purposes and have restricted our reply to ATC operational comment on the need for this in relation to airline operations but not general aviation operations.

10 If, however, there are any other points on which we could advise, we should be happy to co-operate on hearing from you.

Yours faithfully,

T S JOHNSTON
Chairman, Technical Committee
Attachment: A—Extract from ICAO
Doc 4444–RAC/501/9
B—General description of
typical PAR equipment.

ATTACHMENT A

Extract from ICAO DOC 4444–RAC/501/9 Chapter X

3.4.3 Radar-monitored approach

3.4.3.1 An approach made on a pilot-interpreted final approach aid should be monitored by precision approach radar:

(a) whenever the meteorological conditions are below such minima as may be prescribed by the appropriate authority; and otherwise

(b) at the request of the pilot; or

(c) when required by the non-radar controller.

3.4.3.2 The approach shall be monitored with reference to an approach funnel established as follows around the lines portraying on the radar display the nominal track and nominal glide path of the pilot-interpreted aid (see Note 1 below).

Horizontally (*azimuth*)

½ nm	30 metres (100 feet) L/R
1 nm	60 metres (200 feet) L/R
1½ nm	90 metres (300 feet) L/R
2 nm	120 metres (400 feet) L/R
3 nm	180 metres (600 feet) L/R
4 nm	240 metres (800 feet) L/R
5 nm	300 metres (1000 feet) L/R
6 nm	360 metres (1200 feet) L/R

Vertically (*elevation*)

½ nm	±15 metres (50 feet)
1 nm	±15 metres (50 feet)
1½ nm	±23 metres (75 feet)
2 nm	±30 metres (100 feet)
3 nm	±45 metres (150 feet)
4 nm	±60 metres (200 feet)
5 nm	±75 metres (250 feet)
6 nm	±90 metres (300 feet)

Note 1. It must be appreciated that the Precision Approach Radar glide path and nominal track do not necessarily coincide with the nominal glide path and nominal track of the pilot-interpreted aid.

Note 2. Distances are from touchdown.

Note 3. L/R denotes "Left or Right of track".

3.4.3.3 The aircraft shall be informed that its approach is being monitored by Precision Approach Radar and that information will be transmitted and advice provided as necessary. However, the transmissions made by the radar controller should be kept to a minimum so that the pilot's concentration on the use of the pilot-interpreted aid is disturbed as little as possible.

3.4.3.4 *Azimuth displacement*

3.4.3.4.1 The aircraft shall be informed:

(a) if, at any time during its final approach, the aircraft flies outside the lateral limits of the approach funnel, or if its movement away from the nominal track is such that it appears that the aircraft will shortly go outside the funnel;

(b) if, in the final stage of the approach, the aircraft diverges from the nominal track to the extent that successful completion of the approach appears unlikely; and if the aircraft diverges from the nominal track in a dangerous manner it should be advised to initiate a missed approach.

3.4.3.5 *Elevation displacement*

3.4.3.5.1 The aircraft shall be informed:

(a) if, at any time during its final approach, the aircraft flies above the approach funnel, or if its movement away from the nominal glide path is such that it appears that the aircraft will shortly go above the funnel; however, at no time during the approach should the radar controller actually advise the pilot to adjust his rate of descent or to initiate a missed approach because of the aircraft's displacement above the nominal glide path;

(b) if, at any time during its final approach, the aircraft flies below the approach funnel, or if its movement away from the nominal glide path is such that it appears that the aircraft will shortly go below the funnel;

(c) if, following receipt of information that it is too low, the aircraft does not adjust its rate of descent, or if at any time the aircraft descends rapidly below the nominal glide path; in these cases, the radar controller should advise the aircraft to maintain its present level, or to climb, according to circumstances, using the same procedures as for a precision radar approach (see 3.4.2.5).

3.4.3.6 Regardless of the type of approach being monitored, the provisions of information or advice should be terminated and the aircraft so informed when the aircraft reports the approach lights or the runway in sight, whichever is the earlier. However, if the aircraft reaches the position where the approach funnel terminates without making such a report, and the approach is continued, then the progress of the flight should continue to be monitored to the extent possible.

3.4.3.7 The radar controller in charge of the precision approach should continuously be prepared to take over for a precision radar approach, at the request of the aircraft. In the event of the aircraft being unfavourably positioned for a successful precision approach, radar vectoring should be provided so as to reposition the aircraft for another precision approach.

ATTACHMENT B

General Description of Typical PAR Equipment

Wavelength	3 cm (X-band)
P.R.F.	2000 pulses/second
Coverage	Range 10 nm approx. Horizontal (Azimuth sector) 20° Vertical (Elevation sector) 7°
Rate of Scan	Azimuth Antenna 1 scan/second Elevation Antenna 1 scan/second Note: Rapid scan of 4 scan/second may be used for short periods on some equipment.
Beam Dimensions	Azimuth 1·5° wide 0·6° deep Elevation 3° wide 0·4° deep
Servo System	Azimuth Antenna can be servo-ed (in elevation) through 7° whilst scanning through a sector of 20° (in azimuth) Elevation Antenna can be servo-ed (in azimuth) through 20° whilst scanning through a sector of 7° (in elevation)
Display	Expanded Partial Indicator — This provides a large picture of a small sector. It can give range and bearing, or range and deviation from a defined track or glide path within the sector.
	Elevation Display One EPI set at 10 nm range One EPI set at 3 nm range
	Azimuth Display One EPI set at 10 nm range One EPI set at 3 nm range
	Note 1 The 10 nm Azimuth and Elevation displays are grouped together and may be displayed on a single 12-inch radar scope; the 3 nm displays are similarly grouped and displayed.
	Note 2 The resultant Azimuth and Elevation pictures are expanded by a factor of 9 (approx) on the 10 nm displays, and by a further factor of 3 (approx) on the 3 nm displays, thus providing an extremely accurate display of the aircraft's approach especially in the final stages and during the flare-out.
Accuracy	The instrumental accuracy of the PAR system is: in Elevation 0·2% of the aircraft's range in Azimuth 0·4% of the aircraft's range

APPENDIX 9

Analysis of the approach path at Heathrow Airport

Note by DORA

Introduction

1 Over the past few years quite a large number (about 1500) of aircraft final approaches and landings have been measured in fair weather/good visibility conditions, using a camera system, with regard to lateral and vertical displacements from the glide path and runway centreline. These were made to obtain a reasonably sized sample (about 750 of them have been analyzed so far) and an analysis of what might be roughly termed "approaches during normal or typical conditions".

2 To follow up the "fair weather" measurements for comparison it was decided to study approaches made in "poor visibility" conditions — Runway Visual Range of about 1200 metres or less — using an X-band lock-follow radar. Some 200 flight paths were measured during the autumn of 1968 and the winter period of 1968/69. The purpose of the study was to develop a method or basis which could be used to distinguish the relative incidence or trend of risk in approach flights with reducing visibility conditions. As yet, we have not satisfactorily developed a method by which relative risks can be estimated although work is continuing to try to establish whether this is possible, and at least to provide a general "quality control" monitor of landing performance.

3 In general, for both fair weather and poor visibility conditions the distributions of displacements show a marked departure from the Gaussian distribution, especially in the "tail" region. Broadly, for the fair weather sample the frequency of approaches which show a lateral excursion from the mean flight path of more than 6 standard deviations at some point on the approach is about 1 in 500; beyond 3 standard deviations the frequency is about 1 in 50. For the smaller sample of 200 approaches in poor visibility, the frequency of approaches showing more than 3 standard deviations at some point on the approach point is about 1 in 20. Thus there may be greater risk in these conditions — although up to certain "limit", as yet undefined, greater dispersion about the glide path does not necessarily imply a greater ensuing risk of accident.

Poor Visibility Study

4 The report of the poor visibility sample (200) of approaches is still very much in draft form. Therefore we have selected, for this brief note, the approaches somewhat arbitrarily termed "abnormal" — ie showing more than 4 standard deviations from the RVR class mean at some point or points in the approach. These are summarized in the attached Table (Appendix A).

5 Measurements at the runway threshold indicate that for those approaches exhibiting a large excursion from the mean in the horizontal plane, at other points of the approach there was time for the pilot to make the necessary correction after he saw the approach or runway lights: for the samples we have, in the visual phase *at the threshold* lateral positioning was no worse, statistically, in poor visibility conditions than in the fair weather/good visibility conditions. Although it must be noted that our poor visibility sample sizes (with respect to RVR classes) were somewhat small.

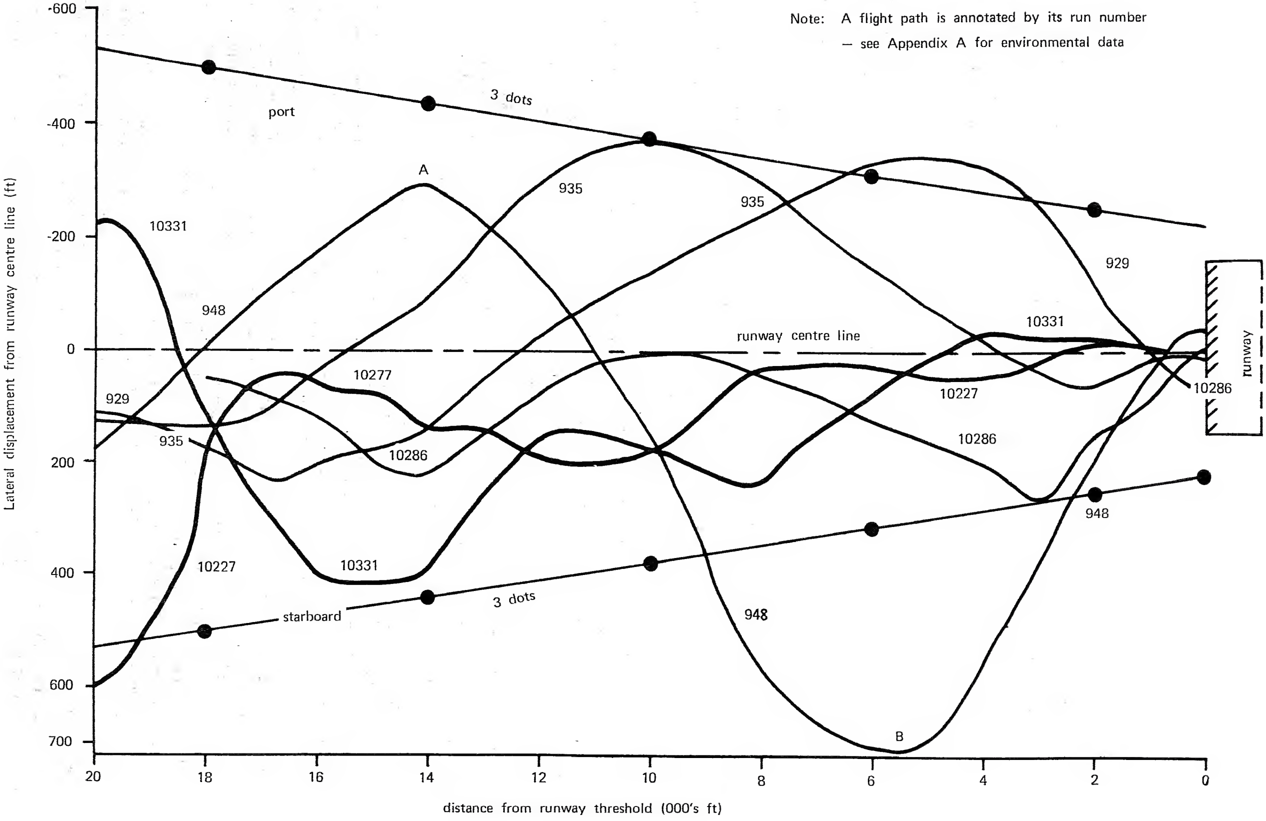
6 In the vertical plane there was more tendency for the aircraft at Heathrow to cross the threshold somewhat higher in poor visibility conditions than in fair weather indicating, possibly, that with a long runway available pilots prefer to get a good view of the approach aids or runway before making an attempt to land. However at Kennedy airport an opposite trend in poor visibility conditions has been noted — pilots seem to prefer to "duck under" at the threshold on 4R runway at Kennedy.

7 Of the approaches in poor visibility conditions there were three instances in the vertical plane when the aircraft was further from the glide path than would correspond to a "5 dots" excursion on the ILS meter and within about 1½ miles or about one minute from the threshold of the runway. In the horizontal plane there was only one such event. In these cases the ILS needle was "off the scale" and yet the pilot was able to correct and make a successful landing. The flight paths of these unusual occurrences are plotted on Figures 1 and 2 attached.

8 There is therefore some evidence that the ability to make a large and late correction is there, and that this is a correction which should be readily detected, because it is "off the scale" of the ILS meter in the aircraft. For approaches which showed points well dispersed from the mean at distances greater than 1½–2 miles or so from threshold there would, of course,

FIGURE 1. Radar measurements of aircraft approaches at Heathrow Airport

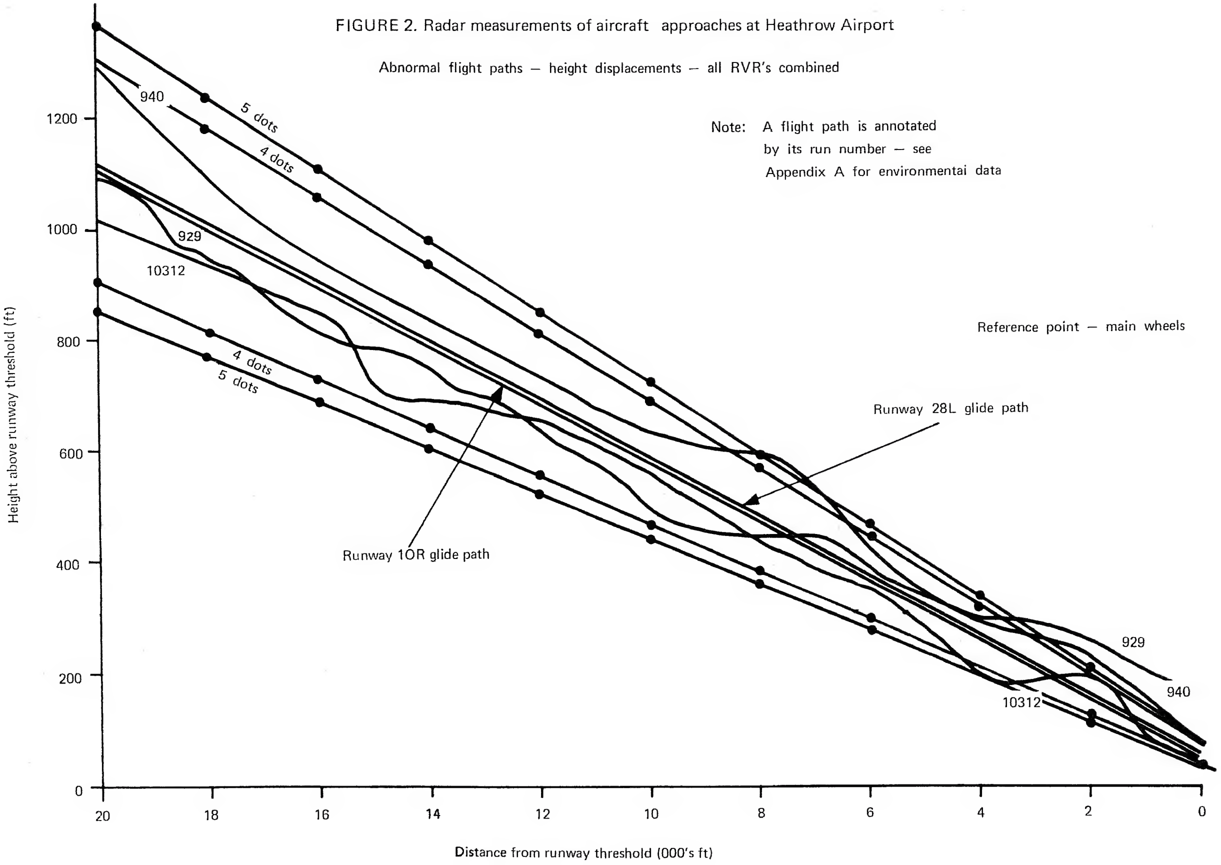
Abnormal flight paths – lateral displacements – all RVR's combined



Note: A flight path is annotated by its run number – see Appendix A for environmental data

FIGURE 2. Radar measurements of aircraft approaches at Heathrow Airport

Abnormal flight paths – height displacements – all RVR's combined



Note: A flight path is annotated by its run number – see Appendix A for environmentai data

Reference point – main wheels

be more time and space available for the appropriate correction manoeuvres.

9 The table in Appendix B shows the concurrent dates and times when PAR was employed on monitoring duties and while the DORA measurements during poor visibility conditions were being made. Apparently, there is no mention of any major interventions or assistance with PAR in the ATC records during the recorded periods. In fact, during the morning of 28.11.68 the Summary Table (Appendix A) lists four abnormal flight paths to have occurred; however there is no record of PAR being employed during this period.

Conclusions

10 (a) There is evidence, from the final approach samples measured at Heathrow, of statistically greater displacements from the glide path occurring during "poor visibility" approaches as compared with "fair weather" approaches. In poor visibility conditions several "abnormal" approaches were measured, but all were completed successfully.

(b) In the visual phase, at the threshold of the runway, lateral positioning is apparently no worse in poor visibility conditions than in fair weather. However with regard to vertical positioning at the threshold there was a decided tendency for aircraft to cross significantly higher in poor visibility conditions than in fair weather conditions.

(c) Although for the most part PAR was also in operation during the poor visibility approaches being measured there is no information from ATC records of specific PAR interventions or assistance for any of these approaches.

J E F CLARKE
DD/ORA
6 April 1970

APPENDIX A

Summary of abnormal trajectories

					CLOUD				CLASSIFICATION (see Notes below)							
Date	*Run number*	*Aircraft type*	*Approach mode*	*Runway*	*Amount*	*Height (ft)*	*RVR metres*	*Wind DIR/KTS*	*RVR Classification*	*Position of abnormal measurement from threshold*	*Mean of class*	*SD of class*	*Observed value*	*Number of SD's away from class mean*	*Remarks*
28.11.68	929	707	—	28L	1/8	12,000	600	Calm	All RVRs	LD 3500 ft	11 ft	69 ft	−296 ft	4.4	(Referred distances are distances back from threshold.)
28.11.68	929	707		28L	1/8	12,000	600	Calm	All RVRs	HT 1000 ft	97 ft	25 ft	212 ft	4.6	
28.11.68	929	707		28L	1/8	12,000	600	Calm	All RVRs	HT AWOP (3)	89 ft	23 ft	205 ft	5.0	
28.11.68	935	707	—	28L	1/8	12,000	600	Calm	All RVRs	LD 10,000 ft	24 ft	73 ft	−371 ft	5.4	
28.11.68	935	707		28L	1/8	12,000	600	Calm	600 m	LD 10,000 ft	−11 ft	90 ft	−371 ft	4.0	
28.11.68	940	Visc.	—	28L	1/8	12,000	700	030/05	All RVRs	HT RMS	0.15°	0.08°	0.51°	4.5	Above glide path continually from 28,000 ft
28.11.68	940	Visc.		28L	1/8	12,000	700	030/05	All RVRs	HT 8000 ft	457 ft	25 ft	598 ft	5.6	
28.11.68	940	Visc.		28L	1/8	12,000	700	030/05	700 m	HT RMS	0.15°	0.09°	0·51°	4.0	
28.11.68	940	Visc.		28L	1/8	12,000	700	030/05	700 m	HT 8000 ft	459 ft	29 ft	598 ft	4.8	
28.11.68	948	707	—	28L	1/8	12,000	800	Calm	All RVRs	LD RMS	0·19°	0·16°	1·32°	7.1	On runway centreline at 30,000 ft 50 ft starboard between 25,000 ft and 30,000 ft. 200 ft starboard between 20,000 ft and 23,000 ft.
28.11.68	948	707		28L	1/8	12,000	800	Calm	All RVRs	LD 8000 ft	19 ft	79 ft	550 ft	6.7	
28.11.68	948	707		28L	1/8	12,000	800	Calm	All RVRs	LD 6000 ft	17 ft	83 ft	698 ft	8·2	
28.11.68	948	707		28L	1/8	12,000	800	Calm	All RVRs	LD 3500 ft	11 ft	69 ft	487 ft	6·9	
28.11.68	948	707		28L	1/8	12,000	800	Calm	All RVRs	LD AWOP (1)	10 ft	57 ft	311 ft	5·3	
28.11.68	948	707		28L	1/8	12,000	800	Calm	800 m	LD 8000 ft	34 ft	111 ft	550 ft	4·7	
28.11.68	948	707		28L	1/8	12,000	800	Calm	800 m	LD 6000 ft	38 ft	144 ft	698 ft	4·6	
24.2.69	10,227	DC6		10L	8/8	300	800	070/10	All RVRs	LD 20,000 ft	36 ft	123 ft	617 ft	4·7	60 ft port between 22,000 ft and 28,000 ft
17.3.69	10,286	DC8	Manual ILS + FD	10R	8/8	200	700	070/08	All RVRs	LD AWOP (1)	10 ft	57 ft	264 ft	4·5	
17.3.69	10,286	DC8	Manual ILS + FD	10R	8/8	200	700	070/08	700 m	LD AWOP (1)	13 ft	59 ft	264 ft	4·3	
18.3.69	10,312	707	Manual ILS + FD	10R	3/8	200	700	080/10	700 m	HT 15,000 ft	831 ft	25 ft	714 ft	4·7	
18.3.69	10,331	DC8	Manual ILS + FD	10R	7/8	500	900	090/10	All RVRs	LD 15,000 ft	35 ft	94 ft	423 ft	4·1	350 ft starboard at 28,000 ft.

Notes:

(1) Data was pooled into an "All RVRs" class, and then into separate classes of RVRs of 600, 700, 800 and > 800 metres.

(2) Comparisons between the classes were made for *Lateral Displacement* from runway centreline (coded LD above) and *Height* (coded HT above) at distances from threshold of 20,000, 15,000, 10,000, 8000, 6000, 3500 and 1000 feet. Displacement port is negative.

(3) Further comparisons of LD and HT were made at points:
AWOP (1) defined as the distance from threshold at which the nominal aircraft height is 200 feet above threshold level.
AWOP (2) defined as the distance from threshold at which the nominal aircraft height is 150 feet above threshold level.
AWOP (3) defined as the distance from threshold at which the nominal aircraft height is 100 feet above threshold level.

(4) Angular displacements (RMS) about the centreline (LD) and glide path (HT) between 15,000 feet and 3500 feet from threshold were also compared. This gave a measure of the track keeping accuracy down to about 250 feet height, and is quoted in degrees.

(5) Aircraft lateral position is measured to the aircraft nose, and height is relative to the main wheels.

APPENDIX B

Radar measurements of flight paths of aircraft on final approach in low visibility at Heathrow Airport

1 Listed in the table below are dates and times when data were collected by the DORA radar, and when PAR was monitoring ILS approaches.

2 Apparently there is no mention of any major interventions, in the ATC records, during the use of the PAR. It can be seen from the table that except for short periods on 25.2.69 and 28.2.69 and the morning period of 28.11.68 the PAR was monitoring during all other times the radar tracking was carried out. However it is of interest that during the morning of 28.11.68 the Summary Table of Abnormal Trajectories lists four abnormal flight paths.

	DORA Radar		*PAR in use to monitor ILS approaches*	
Date	*Tracking period (Hrs. GMT)*	*Approach Runway*	*Runway*	*Period (Hrs. GMT)*
10.7.68	1415–1530	10L	10L	1050–1525
23.8.68	0810–0930	28R	28R	0310–0930
22.10.68	0830–0900	10L	10L	0630–0930
28.11.68	0930–1200	28L	No record of PAR on R/W 28L	
	1350–1415	28L	28L	1350–1430
3.1.69	0815–1100	28L	28L	0745–1115
5.2.69	0800–1430	28L	28L	0845–1430
24.2.69	1000–1130	10L	10L/10R	0845–1325
25.2.69	1100–1115	28L	28L	0215–1505
	1450–1600	28L	28L	1620–1653
28.2.69	0940–1015	10L	No record of PAR	
17.3.69	0830–1500	10R	10L/10R	0001–1640
18.3.69	0915–1600	10R	10L/10R	0001–2359
19.3.69	0915–0940	10L	10L/10R	0001–1030

APPENDIX 10

Board of Trade,
Directorate of Operational Research and Analysis,
Building 473,
Heathrow Airport, London,
Hounslow,
Middlesex.

A report of Precision Approach Radar intervention during monitoring of an ILS approach

After completing please return to the address above

1 Date
2 Time
3 Airport
4 Runway
5 Weather conditions
6 Aircraft type
7 Call sign or Flight Number

8 Company
9 Company limits
10 Captain's duty time up to PAR intervention
11 Was PAR requested by captain
12 Was PAR intervention a major factor in making a successful landing

13 Description of PAR intervention and action taken

14 Captain's comments on PAR service — This intervention or general aspects

15 R/T Transcript
Requested from and date
Received

16 O.R.A.4 Data
Camera
Radar

ORA4
February 1970

TABLE 1
Summary of Accidents and Significant Incidents Involving ILS Approaches Without PAR

Date	*Aircraft*	*Registration*	*Operator*	*Location*	*Brief circumstances*	*Probable causes*
17.2.59	*Viscount	TC-SEV	Turkish Airlines	Gatwick	Crashed in a wood obscured by fog 3 miles from threshold.	Not determined.
19.1.60	Caravelle	OY-KRB	SAS	Esenboga (Ankara)	Collided with ground about 6 miles from threshold.	Unintentional descent below authorized minimum flight altitude on final approach.
4.2.60	L-188A	N5532	Eastern	New Orleans	After touchdown left of centreline aircraft ran off runway into mud.	Failure of pilot to properly align aircraft with runway prior to landing in restricted visibility.
7.2.60	Boeing 707	N-725PA	PAWA	Los Angeles	During left turn to correct misalignment with the runway, numbers 1 and 2 jet pods scraped the runway.	Improperly executed ILS approach. Inadequate supervision by the captain.
10.2.60	L-1049H	CF-TEZ	TCA	Toronto	Struck trees on approach; made emergency wheels-up landing; came to rest 1370 ft past end of runway.	Was flown below the approved minimum IFR altitude.
9.5.60	Boeing 707	N 765 T	TWA	New York	Visual contact established when too high and too close to threshold to land safely. Undercarriage retracted for go-around; collapsed on touchdown.	Poorly conducted instrument approach necessitating a go-around which was initiated too late and improperly executed.
31.10.60	DC3	G-AGZB	BEA	Birmingham	After landing in fog, aircraft over-ran the runway.	Not stated. ILS off flags appeared briefly at 2 m. Unknown whether on glide path at 1 m. Uncertain whether PAR monitoring would have been effective.
28.2.61	DC7C	N-745PA	PAA	Stuttgart and Nuremburg	Struck 10-ft mound located 66 ft short of threshold and 149 ft from edge of runway. Lost undercarriage and one engine but flown to another airport for landing on fuselage.	Improperly executed instrument approach during which aircraft descended below obstructing terrain.
16.4.61	DC8	N 805 E	Delta	Detroit	Struck trees 6000 ft short of runway and 290 ft to right of extended centreline. Subsequent missed approach and second ILS landing were successful.	Improperly executed instrument approach resulting in descent below obstructions.
29.7.61	Boeing 707	N-7509A	American	Los Angeles	Heavy landing, with subsequent nosegear failure.	Improperly executed approach and level-off.
4.3.61	*Viking	G-AHPM	Cunard Eagle	Stavanger	Collided with mountain 18 m northeast of airport.	
26.9.61	Caravelle	HB-ICW	Swissair	Basle	Struck ground about 140 yds from threshold, lost right leg of main landing gear, continued to another airport for emergency landing.	Pilots gave insufficient attention to weather and allowed aircraft to descend below minimum safe altitude.
19.11.61	DC3	N.48V	Piedmont	Near Bristol, Tenn.	After passing through localizer beam and turning right to establish the localizer inbound aircraft struck ground objects. Recovered with subsequent successful ILS approach.	Improperly executed instrument approach resulting in descent below obstructing terrain. Lack of attention by pilots. Inadequate supervision by captain.

* Indicates that further details are given in the body of this report.

TABLE 1 — *continued*

Date	*Aircraft*	*Registration*	*Operator*	*Location*	*Brief circumstances*	*Probable causes*
13.5.62	Comet 4B	G-APMG	Olympic	Tel Aviv	After approach in fog using ILS localizer only lost visual reference and left runway.	Not stated.
27.11.62	Boeing 707	PP-VJB	Varig	Lima	Crashed into mountain	Unexplained deviation from the track for instrument approach along the ILS back course.
28.12.62	Carvair	G-ARSF	Channel Air-Bridge	Rotterdam	Struck dyke 800 ft short of threshold in reduced visibility.	Final stage of approach was below the normal glide path, with insufficient engine power. Speed of descent too high in relation to horizontal distance to be covered.
17.3.63	*Viscount	G-AOHO	BEA	Berlin (Tegel)	Struck ground short of displaced threshold and again just before the runway concrete. Nose-wheel collapsed.	Tegel is military aerodrome. Captain of G-AOHO not aware of displaced threshold.
18.3.63	DC3	N 143 D	Ozark	Peoria, Ill.	Struck trees about 2 miles from runway during a back course ILS approach.	Improperly executed instrument approach in turbulent air, resulting in descent below obstructing terrain.
24.8.63	F27	N 2707	West Coast Airlines	Calgary	Struck ground 8000 ft from threshold and 420 ft to right of centreline.	Failure of pilot in command to maintain approved minimum altitude. Failure of co-pilot to monitor final stages of approach.
2.9.63	*L 1049	EC-AMQ	Iberia	Gatwick	Brushed trees 1¾ nm from threshold.	Descent below safe approach path while landing without glide path at night in low cloud.
7.4.64	Boeing 707	N 779 PA	PAWA	J F Kennedy Airport	Touched down at far end of runway, over-ran and came to rest in Thurston Basin.	Captain deviated from glide slope, resulting in touchdown at a point and speed which precluded stopping on remaining runway.
1.7.64	Boeing 720B	N 7528A	AAL	Jamaica, NY	Landed to right of centreline and veered off runway in conditions of heavy precipitation and reduced visibility.	Failure to discontinue the approach in bad weather, resulting in improper alignment and loss of directional control.
30.12.64	C46A	N 608Z	Zantop	Detroit	Crashed 2 miles short of runway after steep banked left turn following advice aircraft was to right of ILS localizer course.	Loss of control during night instrument approach in adverse weather. Undetermined reason.
14.4.65	Dakota 6	G-ANTB	BUA	Jersey	While landing in fog, struck approach lights and crashed about 800 yds short of threshold.	Flown below safe approach path in conditions of very low cloud and poor visibility. Pilot disregarded his operations manual.
15.2.66	Caravelle	VT-DPP	Indian Airlines	New Delhi	Hit concrete approach light pole and crashed.	Abandonment of the ILS approach at too early a stage in poor visibility.
21.1.67	*Douglas C54	G-ASOG	Air Ferry	Frankfurt	Collided with trees 2700 m short of runway and destroyed by fire.	Incorrect altimeter settings.

* Indicates that further details are given in the body of this report.

TABLE 1 — *continued*

Date	*Aircraft*	*Registration*	*Operator*	*Location*	*Brief circumstances*	*Probable causes*
20.11.67	CV880	N 821 T	TWA	Cincinatti	Crashed 10,000 ft short of threshold. ILS glide slope, approach lights and middle marker were inoperative.	Not stated.
3.12.67	Trident	G-ARPU	BEA	Copenhagen	Full power touchdown 30 yds short of runway, causing substantial damage. ILS glide path not available, no VASI, runway and approach lights not on.	Not yet determined.
7.1.68	DC7B	SE-CNF	Internord	Salzburg	Collided with high-tension power line in low visibility, landed safely.	Approach commenced in below minima condition and continued below safe altitude.
3.3.68	Britannia	OE-MBB	Cubana	Gander	Struck trees 4 miles from runway during a back beam ILS approach.	Not stated.
3.6.68	Boeing 727	N 831 TW	TWA	La Guardia	Struck approach lights 700 ft short of threshold causing substantial damage.	Not stated.
21.6.68	PA 23	G-ATCM	Aircruise Operating Limited	Brest	Struck ground short of runway.	Moisture in pitot may have resulted in altimeter error. ILS may have been faulty. PAR monitoring may have helped.
10.8.68	FH-227		Piedmont	Charleston	Struck trees 350 ft short of runway in restricted visibility. ILS glide slope was inoperative.	Not stated.
27.10.68	Vanguard	G-APEN	BEA	Belfast	Over-ran runway after landing.	Not stated.
22.11.68	DC8	JA-8032	JAL	San Francisco	Landed in San Francisco Bay 5600 ft short of runway. Stated to be a fully "coupled" ILS using autopilot.	Improper application of prescribed procedures to execute an automatic-coupled ILS approach.
27.12.68	CV580	N 2405	North Central	Chicago	Struck hangar 1500 ft from runway after apparently attempting a go-around.	Still under investigation.
5.1.69	*Boeing 727	YA-FAR	Ariana	Gatwick	Collided with trees and houses 2400 m before threshold.	
13.1.69	DC8	LN-MOO	SAS	Los Angeles	During back course ILS approach landed in the ocean 6 miles short of airport.	Still under investigation.

* Indicates that further details are given in the body of this report.

TABLE 2

Summary of Accidents and Significant Incidents Involving ILS Approaches Monitored by PAR

Date	*Aircraft*	*Registration*	*Operator*	*Location*	*Brief circumstances*	*Probable cause*
30.10.61	*Viscount	G-AODH	BEA	Frankfurt/Main	Struck ground alongside runway during missed ILS approach.	Pilot flew below the critical height in inadequate surface visibility. Approach was monitored by PAR.
3.2.63	*L1049H	N 9740 Z	Slick	San Francisco	Struck runway approach lights 1170 ft short of threshold.	Continuation of approach after loss of visual reference below authorized minimum. Inadequate monitoring by PAR.
8.2.63	*Viscount	G-ARBY	BUA	Gatwick	Landed off runway and nose-wheel collapsed.	Not stated. Approach was monitored by PAR.
11.3.64	*DC7C	PH-DSN	KLM	Geneva	Landed on last runway section, overshot and collided with anti-blast barrier. (ILS directly intercepted; approach perfect in azimuth, could not rejoin descent centreline in spite of PAR advice.)	Captain landed without knowing his position relative to length of runway; instrument approach objectively missed.
27.10.65	*Vanguard	G-APEE	BEA	Heathrow	Crashed and caught fire during an overshoot.	Approach was monitored by PAR.
18.2.66	*DC6B	OO-ABG	BIAS	Milan	Collided with trees and crashed.	Attempted landing in conditions below company minima. Misuse of throttle. Approach monitored by GCA.
30.6.67	*Caravelle	HS-TGI	Thai Airways	Kai Tak, Hong Kong	Crashed into sea ½ mile from threshold.	Crew failed to adhere to company procedure; inadequate monitoring by captain; mishandling after descent below minimum altitude. Approach monitored by PAR.
29.9.67	*Comet 4C	ST-AAX	Sudan Airways	Rome	Lost visual contact at 100 ft, landed at angle of 10° to runway heading and ran off runway.	Not stated. Approach was monitored by PAR.

* Indicates that further details are given in the body of the report.

Glossary of abbreviations

ADF	Automatic Direction Finding
AFS	Airfield Fire Service
ARB	Air Registration Board
ATC	Air Traffic Control
ATCO	Air Traffic Control Officer
BALPA	British Air Line Pilots Association
DFTI	Distance From Touchdown Indicator
DME	Distance Measuring Equipment
DORA	Directorate of Operational Research and Analysis, Board of Trade
GCA	Ground-Controlled Approach
IATA	International Air Transport Association
ICAO	International Civil Aviation Organisation
IFALPA	International Federation of Air Line Pilots Associations
IFR	Instrument Flight Rules
ILS	Instrument Landing System
Cat I	Operation down to 200 feet decision height and 800 metres RVR with a high probability of approach success
Cat II	Operation down to 100 feet decision height and 400 metres RVR with a high probability of approach success
Cat IIIA	Operation, with no decision height limitation, to and along the surface of the runway with external visual reference during the final phase of the landing down to RVR minima of 200 metres
Cat IIIB	Operation, with no decision height limitation, to and along the surface of the runway and taxiways with visibility sufficient only for visual taxying corresponding to a RVR of not less than 50 metres
Cat IIIC	Operation, with no decision height limitation, to and along the surface of the runway and taxiways without reliance on external visual reference
NDB	Non-Directional Beacon
NLR	National Lucht-En Ruimtevaartlaboratorium (National Aerospace Laboratory). The Netherlands
OCL	Obstacle Clearance Limit
PAR	Precision Approach Radar
PPI	Plan Position Indicator

QFE	Atmospheric pressure at aerodrome elevation (or runway threshold)
QNH	Altimeter sub-scale setting to obtain elevation when on the ground
RVR	Runway Visual Range
SBA	Standard Beam Approach
VASI	Visual Approach Slope Indicator
VHF	Very High Frequency
VOR	Very High Frequency Omni-Directional Radio Range

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